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STEERING HOUSEHOLD CONSUMPTION WITH CARBON FOOTPRINT DATA

A CRITICAL ASSESSMENT

Marja Salo

DOCTORAL DISSERTATION

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ABSTRACT

This dissertation studies how consumption data and applications such as carbon footprint calculators are used in steering household consumption (food, housing, travel, consumption of other goods and services). In addition to statistical data and analysis showing aggregated figures over populations, data and applications which monitor, estimate and provide feedback have been developed by various types of organisations. The tailored data on consumption are intended to inform and guide people on their carbon footprint and energy consumption. The study aims to address the research gap between the optimism that data-based applications can steer consumption and the critique presented of this view. To this end, the thesis examines the data-based applications and their use in the context of sustainable consumption policies.

It draws on five articles that focus on household consumption patterns and applications which measure and steer consumption and related carbon footprints. The studies suggest that using the data as soft, information-based measures to persuade people to change their consumption patterns and doings provides novel opportunities for steering. At the same time, challenges such as the lack of long-term engagement with the applications, as shown in the studies, should also be taken seriously when considering the role of voluntary data-based measures in the sustainable consumption policy mix.

The findings demonstrate that consumption and carbon footprint data have persuasive potential when they are used to support the activities and processes of committed actors. This is particularly the case when participants invest resources, time and effort in developing skills or adjusting the material environment to support more sustainable consumption and practices. Nevertheless, integrating the tools into the everyday lives and doings of ordinary people in order to steer them presents challenges.

A novel contribution of this dissertation is to apply practice theory to unfolding these challenges. Practice thinking reveals how tension about, and resistance to, using footprint calculators and similar tools, then changing one's doings according to the tailored advice, arises not only from the characteristics of the applications and interactions of people and applications: current taken-for-granted patterns of doing, perceptions of normal standards of comfort and convenience, the interlinked nature of everyday activities and competing priorities also hinder actions and ambition levels.

Based on the findings, the dissertation provides recommendations for future practical initiatives and research on data-based applications to steer consumption from an environmental sustainability perspective. The results call for recognition of the prevalent forms of doings and circumstances instead of leaving them out of analysis of data-based applications and steering. The dissertation comprises critical reflection and discussion of the role and expected impact of the mechanisms of data-based steering and policies.

TIIVISTELMÄ

Tässä väitöskirjassa tutkitaan kulutustiedon ja -sovellusten kuten hiilijalanjälkilaskureiden käyttöä kotitalouksien kulutuksen (asuminen, liikkuminen, ruoka, muut tavarat ja palvelut) ohjauksessa. Laajojen, kulutusta koskevien aineistojen perusteella voidaan tarkastella kulutuksen yleiskuvaa ja kulutukseen vaikuttavia tekijöitä. Kulutuksen ympäristökuormituksen ratkomiseksi on kehitetty tietopohjaa ja sovelluksia arviointiin, seurantaan ja palautteen antamiseksi. Esimerkiksi hiilijalanjälkilaskureista voi saada räätälöityä tietoa jalanjäljen pienentämiseksi. Väitöskirja yhdistää kulutusseurannan mahdollisuuksiin optimistisesti ja sen vaikutusmekanismeihin kriittisesti suhtautuvia tutkimusotteita. Kulutustietoa ja siihen pohjaavien sovellusten käyttöä tarkastellaan kestävän kulutuksen ohjauskeinojen näkökulmasta.

Väitöskirja perustuu viiteen tutkimusartikkeliin kotitalouksien kulutuksesta, hiilijalanjäljistä ja kulutuksen ohjauksesta. Ne osoittavat kulutustiedon mahdollisuuksia tietoon ja vapaaehtoisuuteen perustuvina ohjauskeinoina. Samalla osatutkimuksista käy ilmi, että haasteet, kuten sitoutumattomuus toistuvaan käyttöön, tulisi ottaa vakavasti arvioitaessa tietoon perustuvien ohjauskeinojen mahdollisuuksia vaikuttaa kulutukseen.

Havainnot osoittavat, että kulutuksen ja tuotannon rajapinnassa kulutus- ja hiilijalanjälkitiedolla voidaan tukea muutokseen sitoutuneiden toimia kulutuksen vaikutusten pienentämiseksi. Ajan ja resurssien käyttö tarvittavien taitojen kehittämiseksi ja muutokset arjen toimintaympäristössä tukevat kulutuksen muutosta ja kestävämpiä käytäntöjä. Toisaalta, kulutusseurannan juurtuminen osaksi arkea ja toimintatapoja ei aina toteudu.

Väitöskirjassa sovelletaan käytäntöteoreettista lähestymistapaa kulutusseurannan ja -ohjauksen haasteiden tunnistamiseen. Käytäntölähtöinen tarkastelu paljastaa jännitteitä ja vastustusta, joita kulutuksen seuranta ja siihen perustuvat toimintaohjeet voivat nostaa esiin. Vaikka tieto kyseenalaistaisi vakiintuneeksi ja yleisesti hyväksytyksi koetun toiminnan, sitä saatetaan pitää välttämättömänä eikä toimintatavalle ei koeta olevan vaihtoehtoa. Tällöin kulutussovellusten mahdollisuudet vaikuttaa kulutukseen liittyvät osittain ympäröivän yhteiskunnan normeihin ja toimintaympäristöön. Vaikka osatutkimuksissa nousee esille kulutustietojen ja sovellusten kehitystarpeita, ne eivät yksin ratkaise kulutusseurannan ja -sovellusten vaikuttavuutta.

Tulosten perusteella ehdotetaan toimia kulutuksen ohjaukseen ja sovelluskehitykseen, sekä jatkotutkimustarpeita. Kulutustieto ja -sovellukset ja niiden tavoitellut vaikutusmekanismit tulisi nähdä suhteessa yhteiskuntaan, vakiintuneisiin käytäntöihin ja toimintaympäristöön. Väitöskirjassa pohditaan kriittisesti kulutustiedon mahdollisia mekanismeja ja rooleja kestävän kulutuksen ohjauksessa.

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This PhD project was motivated by my desire for deeper understanding of the topic and applications I had been exploring on for years: sustainable household consumption and environmental footprint calculators. It has been a great privilege to turn this interest into a PhD research project.

During the final phases of writing the dissertation, my life and the work was shaped by two partly overlapping periods: living in Kigali, Rwanda, and the Covid-19 pandemic. There is no doubt that these personal and collective experiences have impacted my reflection on the research topic. The time made me even more grateful for all the opportunities I have had in my life so far, including this PhD project.

I am privileged to have had Professor Janne I. Hukkinen and Development Manager (PhD) Ari Nissinen supervising my work. I am most grateful for their excellent guidance in terms of academic research and the encouragement they offered in my pursuit of the task. Janne's accepting me into the Environmental Policy Research Group was invaluable, as were his guidance and comments during the writing process; the assistance was vital to developing my academic writing skills. On the other hand, this thesis would probably never have been started without Ari's support. He encouraged me to materialise my idea of undertaking PhD research, and offered to supervise the work. Furthermore, it has been most rewarding to have Ari as a co-author in three of the articles in the dissertation, as it has allowed us to discuss the research and practice of sustainable consumption in detail. It was also a unique opportunity to be able to work on the dissertation while being affiliated both with SYKE and the University of Helsinki.

I was fortunate to have Hannele Cantell and Minna Lammi as members of my thesis committee; both provided such positive encouragement for this work. I highly value Hannele's expertise in and passion for environmental education. Her commitment to making the world a just and better place through research-based methods has been such a support and inspiration. I cannot thank Minna enough for supporting my work and commenting on my writing way beyond what is expected from a committee member. I have greatly appreciated our enjoyable discussions and the critical comments, especially during the summary writing process, both of which helped to structure and improve the text. I have Minna to thank for the opportunity to participate in a Sustainability Cohort course in 2018 organised by the Centre for Industrial Sustainability, University of Cambridge.

Doing research is collaborative work and co-authoring articles is concrete proof of that. I am delighted and privileged to have had the opportunity to co-author articles with many excellent and enthusiastic colleagues, in addition to my supervisor Ari Nissinen. I want to thank Minna Kaljonen for allowing me to get on board an exciting project on sustainable eating at SYKE. It was a

pleasure to work with Minna, Jari Lyytimäki, Eeva Furman and other colleagues in the project. I would like to acknowledge having had Maija Mattinen-Yuryev as a kind and encouraging co-writer in one article for the dissertation, and a precious support in so many ways during the process, and I was delighted to have Hannu Savolainen and Santtu Karhinen's econometric expertise and co-authorship for another of the articles. Hanna Mela, Juha Peltomaa, Kirsi Mäkinen and Mikael Hildén, thank you for including me in developing the practice framing of smart metering and in writing an article. I would also like to thank external project partners Raimo Lilja, Emilia Olkanen, Mia O'Neill and Martina Uotinen for their committed collaboration and contributions to one of the articles included in this dissertation. All the collaboration listed here has taught me a lot about the perspectives of different disciplines on the topic of household consumption, and how to measure and steer it. It has also provided an excellent opportunity to observe and learn about the diversity in the details of working practices in the research community. Thank you all for the enjoyable and most inspiring collaboration.

Pre-examiners Dr Annelise de Jong and Professor Jukka Heinonen provided insightful comments on the manuscript. I found the suggestions helpful in improving the dissertation. I would also like to acknowledge Professor Kirsten Gram-Hanssen for agreeing to act as an opponent at my doctoral defence.

Inspiring and fun, colleagues at SYKE have supported me professionally and emotionally throughout the PhD and other project work over the years. I am grateful for having been part of such a community of bright colleagues. There are many to thank in addition to the co-authors already listed, but I would like especially to acknowledge Annukka Berg, Nufar Finel, Jáchym Judl, Kaarina Kaminen, Johanna Laaksonen, Suvi Lehtoranta, Kaisa Manninen, Ville-Veikko Paunu, Anna Repo, Olli Sahimaa, Hanna Savolahti, Mikko Savolahti, Johanna Suikkanen, Pasi Tainio and Saija Vuola for their heart-warming support and inspiration. I also value the institutional support from SYKE in providing me with a desk, working infrastructure and flexibility in terms of space and time during my doctoral studies.

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group and allowing me to get to know colleagues who are doing research from practice theory perspectives in Wageningen.

It was a lucky coincidence that I started my professional career working on sustainable consumption and related footprints. I am most grateful to Michael Lettenmeier and Satu Lähteenoja, who supervised the practical work of my master's thesis in 2007 for the Finnish Association for Nature Conservation. Michael and Satu also offered work opportunities and introduced me to excellent senior experts in sustainability and consumption, including Ari. That opportunity, the cooperative hard work and all the fun kick-started my first decade of working on sustainable consumption and the means to steer it. Thank you.

I was fortunate to have financial support from the Kone foundation for this PhD project. Their boldness in funding my studies allowed me to take time off from the full-time project puzzle and devote it to pursuing studies, getting to know new colleagues and their research, reading and writing. In addition, my contribution to several articles in the dissertation has been partly funded by the Academy of Finland, the Ministry of Environment, the Ministry of Education and the Nordic Council of Ministers.

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Marja Salo
Kigali, January 2021

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I Salo, M., Savolainen, H., Karhinen, S., Nissinen, A. (2021). Drivers of household consumption expenditure and carbon footprints in Finland. *Journal of Cleaner Production,* DOI: 10.1016/j.jclepro.2020.125607.

II Kaljonen, M., Salo, M., Lyytimäki J., Furman, E. (2020). From isolated labels and nudges to sustained tinkering: assessing long-term changes in sustainable eating at a lunch restaurant. *British Food Journal,* DOI: 10.1108/BFJ-10-2019-0816.

III Salo, M., Mattinen-Yuryev, M.K., Nissinen, A. (2019). Opportunities and limitations of carbon footprint calculators to steer sustainable household consumption – Analysis of Nordic calculator features. *Journal of Cleaner Production,* DOI: 10.1016/j.jclepro.2018.10.035.

IV Mela, H., Peltomaa, J., Salo, M., Mäkinen, K., Hildén, M. (2018). Framing Smart Meter Feedback in Relation to Practice Theory. *Sustainability,* DOI: 10.3390/su10103553.

V Salo, M., Nissinen, A., Lilja, R., Olkanen, E., O'Neill, M., Uotinen, M. (2016). Tailored advice and services to enhance sustainable household consumption in Finland. *Journal of Cleaner Production,* DOI: 10.1016/j.jclepro.2016.01.092.

The publications are referred to in the text by their roman numerals.

Article I was co-authored with Hannu Savolainen, Santtu Karhinen and Ari Nissinen. All authors contributed to the conceptualisation of the article. Salo had the main responsibility for writing the original draft, while Savolainen and Karhinen also contributed to original draft writing of Sections 2 and 3. Savolainen and Karhinen had the main responsibility for methodology, and Savolainen conducted the formal analysis. All authors contributed to the reviewing and editing of the original draft.

Article II was co-authored with Minna Kaljonen, Jari Lyytimäki and Eeva Furman. Kaljonen had the main responsibility for conceptualising the study. Salo planned the quantitative data collection together with the co-authors and Salo had the main responsibility for collecting and analysing the data.

Kaljonen and Lyytimäki were principally responsible for planning, collecting and analysis of the qualitative data. Salo participated in qualitative data collection and analysis. Kaljonen had the main responsibility for writing the manuscript, Salo and Lyytimäki also contributing. All authors contributed to the editing of the manuscript.

Article III was co-authored with Maija Mattinen-Yuryev and Ari Nissinen. The data were collected in a Nordic project, and the original idea for which was Nissinen's, Salo had the main responsibility for planning the study, developing the theoretical approach based on practice theories, collecting and analysing data and designing and writing the paper. Mattinen-Yuryev and Nissinen provided valuable suggestions and comments on the structure and content of the article throughout the writing process.

Article IV was co-authored with Hanna Mela, Juha Peltomaa, Kirsi Mäkinen and Mikael Hildén. The author of this dissertation had a major contribution to conceptualisation, methodology, and reviewing and editing, especially regarding the practice theory approach applied in the article. The formal analysis was conducted by Mela who also had the main responsibility for writing, while the co-authors contributed to conceptualisation, methodology, reviewing and editing of the article.

Article V was co-authored with Ari Nissinen, Raimo Lilja, Emilia Olkanen, Mia O'Neill and Martina Uotinen. It builds on empirical cases, pilots, and work conducted in the Ekokoti-project. The original idea for the article came from Nissinen. The author of this dissertation had the main responsibility for designing and writing the paper, including analysis of the cases. All authors contributed to designing and conducting pilots and provided important input for the related Sections 3.3 and 4 in the article.

LIST OF FIGURES AND TABLES

ABBREVIATIONS

EEIO	Environmentally extended input-output analysis
GHG	Greenhouse gas emissions
HBS	Household budget survey
SCP	Sustainable consumption and production

1 INTRODUCTION

If only people knew how problematic the carbon footprint[1] of their ordinary everyday living was, surely they would change it? If only researchers and policymakers knew better how to use data and carbon footprints to rearrange ordinary living, surely we would steer consumption more wisely? Should tailored information turn into actions, we would see many households becoming forerunners in managing their carbon footprints. Information and voluntary behaviour changes also seem to be tempting instruments for policy agendas (Heiskanen et al., 2014). In this dissertation, I aim to identify and demonstrate the opportunities and challenges of using consumption-based data and applications such as carbon footprint calculators to steer household consumption for environmental reasons. Those designing policy need to consider how applications interact with other steering measures and the dynamics of everyday living.

It has become evident that the current volume and patterns of household consumption (housing and energy consumption at home, food, travel, and consumption of other goods and services) is environmentally unsustainable and needs to be steered, for instance, towards mitigating climate change (Hertwich and Peters, 2009; Ivanova et al., 2016). Moreover, the gap between average carbon footprints among populations points to inequalities in standards of living (Druckman and Jackson, 2016; Pan et al., 2019; Wiedenhofer et al., 2017). Therefore, humanity faces the problem of responding to the growing consumption due to the rise of a global middle class while simultaneously complying with decarbonising pathways laid out in the Paris Agreement (Rockström et al., 2017). For instance, in Finland, the average per capita carbon footprint varied between 10.1–12.6 tonnes in 2000–2016 (Savolainen et al., 2019b). Hence, less than one tonne per capita on average (globally) by the year 2050 is estimated to be in line with the 1.5 degrees path (Fauré et al., 2016; Institute for Global Environmental Strategies, Aalto University, and D-mat ltd., 2019; Rockström et al., 2017).

To mitigate climate change, scholars (e.g., Creutzig et al., 2018) argue for the development of demand-side solutions and policies, and measures that tackle the patterns and drivers shaping consumption instead of only relying on efficiency improvements (Creutzig et al., 2016). O'Neill et al. (2018) highlight the need to restructure provisioning systems to meet human needs within the planetary boundaries. In line with these findings, studies have modelled the potential impacts that changes in consumption patterns might have on decreasing the carbon footprint of household consumption (Girod et al., 2014; Moran et al., 2018; Vita et al., 2019); lifestyle changes that contribute to

[1] Carbon footprint refers to life-cycle-wide greenhouse gas emissions of a specific item, service, unit of expenditure or activity.

climate change mitigation pathways have also been examined (van Vuuren et al., 2018). Nevertheless, many suggest caution over expectations of realising the potential through voluntary actions (Dubois et al., 2019; Moberg et al., 2019). Rather, systemic changes (O'Rourke and Lollo, 2015) and policy mixes (Nissinen et al., 2015) are called for to steer household consumption.

Sustainability literature discusses the role of improving efficiency – that is, lowering emissions per unit of goods or service produced – and sufficiency, the volume of consumption. It is relevant to consider how shifts in consumption patterns would occur in terms of these two approaches (for sufficiency and "green consumption" scenarios on lifestyle carbon footprints, see Vita et al., 2019). While environmental policies tackling harmful emissions have contributed to improvements in the efficiency of production, total greenhouse gas (GHG) emissions are increasing due to growing consumption driven by affluence and population growth (Rosa and Dietz, 2012; Wiedmann et al., 2020). For instance, Christensen et al. (2007) illustrated that, despite the success of environmental policies on passenger cars to curb emissions and improve fuel efficiency, other policies and developments have contributed to an overall increase of car use in Denmark between 1982 and 2002. Studies focusing on fuel efficiency (i.e., leaving out driven kilometres) have also shown that improvements may be partially offset if vehicle size and performance increase (Hu and Chen, 2016), and further, that real-world consumption deviates from laboratory tests (Craglia and Cullen, 2019).

Policymaking could benefit from research showing the links between consumption patterns and related GHG emissions. Currently, climate policy relies mostly on territorial emission accounting, such as national inventories of GHG emissions. However, in a globalised economy, production and consumption are often spatially distant. Consumption-based footprint analysis allows this issue to be tackled as it can reveal and help to avoid shifting the burden of production emissions from one country (or region) to another (Hertwich and Peters, 2009; Wiedmann and Lenzen, 2018). The approach also illustrates how emissions from production are derived from demand (Hoekstra and Wiedmann, 2014). Consumption-based emission inventories, such as online Global Carbon Atlas (2020), have emerged; meanwhile, applications focusing on personal or household levels, such as carbon footprint calculators providing tailored estimations and advice, apply consumption-based approaches.

The literature and examples discussed above focus on GHG emissions, which is only one, even if a very important part of the environmental sustainability discussion. Thus, merely steering carbon footprints may not lead to environmentally sustainable consumption (e.g., Laurent and Owsianiak, 2017). Nevertheless, carbon footprint is used as an example of the problematics to steer environmental consequences of consumption.

Technologies to track the primary consumption data, such as smart metering of energy use at home, Geelen et al. (2019) also provide data for tailored communication and feedback. At a time when detailed data and

tracking to improve one's performance in the field of well-being are popular, it is a tempting thought that a similar development could likewise be realised in energy contexts (Strengers, 2013). Primary consumption data, related to energy or expenditure for example, can also be translated into carbon (e.g., Minx et al., 2009) and material footprints (Laakso and Lettenmeier, 2016) among other. Therefore, it is not surprising that there have been a number of attempts and experiments to harness consumption data and footprints to inform people about their consumption and persuade them to change accordingly (e.g., West et al., 2016).

While previous research has identified some potential in data-based steering initiatives, for instance in the field of energy monitoring interfaces (Faruqui et al., 2010), critical voices underline the challenges of embedding data and applications in everyday life (e.g., Hargreaves et al., 2013). There is also a body of research focusing on how to present information persuasively (e.g., Gabrielli et al., 2014; Karjalainen, 2011). However, what remains a relevant but understudied area, beyond user interface design and motivational features, is the dynamics of data, applications and advice when embedded into everyday life and processes, and how this will or should rearrange the material environment and social backdrop for everyday doings.

My approach is to study data and applications as the means to steer household consumption. By steering, I refer to informal strategies to influence consumption patterns. Further, I interpret that formal policies can make use of steering mechanisms such as measures based on consumption-based data and feedback. The types of policy instruments pertaining to sustainable consumption are presented in Section 2.1, and the (potential) contribution of consumption-based data on type of instruments is discussed in Section 4.

The contribution of this dissertation is to provide a novel perspective on data-based applications by broadening the scope from the features of the applications and the abilities and willingness of users to take action accordingly. In other words, the scope extends beyond providing inputs for the development of more engaging applications (see e.g., Biørn-Hansen, 2019) and related initiatives as such, and, rather, explores their role and potential in steering collective consumption patterns and contributing to sustainable consumption policy.

To put the study into context, it builds on three, partly overlapping streams of literature. The first body of research introduces sustainable consumption and production policies as discussed in the academic literature during the first two decades of the 2000s. While there is a wide agreement on the need to decrease carbon footprints and other environmental pressures caused by consumption, expectations of what is required to move towards the target, and assigning responsibilities for doing so remain debated. The chosen paths and policies have implications for balancing the focus on improving the efficiency of production or emphasising its sufficiency.

Second, my understanding of everyday doings and related consumption draws on the practice theory literature (Reckwitz, 2002; Schatzki, 2002;

Shove, 2010; Shove et al., 2012). I apply practice concepts to analyse and reframe empirical data and literature on steering consumption in an everyday context. The aim is to harness practice thinking to understanding consumption and everyday doings as guided and constrained by the material and social environment. Therefore, the approach puts the role of information and rational reflection into the perspective of the everyday.

Thirdly, the dissertation takes stock of the literature on how consumption data and especially carbon footprints have been used, and can be used in the future, to steer household consumption. The focus is especially on consumption-based carbon footprinting, providing methodological and empirical input on how footprints can be estimated and what they have shown in regard to the carbon footprint of household consumption patterns.

The literature on carbon footprint calculators has provided valuable contributions on applications as well as critical notes on the calculation methodologies (Section 2.3). Improvements are necessary if the applications are expected to engage consumers and guide demand in order to have an impact on supply chains (Wood et al., 2017). While the findings are important in advancing the development and use of carbon footprint calculations, some authors suggest on remaining cautious on the effectiveness of these applications whose use is voluntary (Afionis et al., 2017). Although citizens have been reported as accepting the individual approach of the footprint calculators (Gram-Hanssen and Christensen, 2012), criticism is also presented of this focus (Spaargaren, 2011). While carbon footprint calculators have been reported to increase awareness in a longitudinal study in the UK (Büchs et al., 2018), awareness does not necessarily translate into behaviour change.

This dissertation addresses the research gap between the optimism that improved data-based applications can steer consumption and the critique presented of the view that consumption patterns will change due to the better knowledge of their consequences provided by the applications. I aim to unfold the specific characteristics and role of consumption-based data and related applications in policies of sustainable consumption and concrete initiatives to steer household consumption.

Drawing on the existing literature on sustainable consumption policies, and on footprinting and related applications aimed at steering household consumption, I have specified three research questions to guide this study.

RQ1. How can consumption data and carbon footprints contribute to policies of sustainable household consumption?

The first question investigates how consumption-based data have been utilised in steering household consumption, and thus contributing to policies on sustainable consumption. The dissertation draws on an econometric analysis of the expenditure patterns of Finnish households (Article I) and the drivers explaining household expenditure and related carbon footprints. The case studies (Articles II, III and V) and literature review (Article IV) on data-

based applications and their use in steering initiatives are discussed as examples of specific types of policies, as defined in the literature, to steer consumption.

RQ2. How can tailored, data-based feedback support steering initiatives?

The second question focuses on the practical uses and experiences of data on household, individual, or practice-specific consumption patterns in steering such consumption. The steering initiatives capture areas of consumption shown to be relevant in the big picture of household carbon footprints (Article I). I reflect on the experiences reported in the case studies and the literature (Articles II–V) of how data and tools connect with the practices and doings they are supposed to steer. I aim to capture observations that also transcend the immediate characteristics of the data, application and user experience.

RQ3. How does recognition of everyday practice dynamics reveal opportunities for, and limitations to, steering household consumption?

The third question taps into the case studies (Articles II, III and V) and literature review (Article IV) to reflect on how drawing on practice thinking can indicate the potential, and especially the challenges, of data and applications in steering everyday doings. I also build upon findings and conclusions based on a quantitative analysis of consumption patterns and drivers from Article I. The research material for this dissertation enables pinpointing how practice thinking can guide problem framing in the interdisciplinary field of data-based applications and approaches to steering consumption. The findings are also discussed in the light of the practice-based critique of data and information-based steering. While I focus mainly on carbon footprints and the consumption contributing to these footprints, the results provide input to the broader debate on the potential and means of steering household consumption with consumption data and applications.

As the dissertation draws on various types of data, the interpretation and dimensions of a key concept, consumption, needs to be defined. Adopting the practice theory perspective, I interpret household consumption to be a consequence of everyday doings. According to practice scholars (Shove, 2003; Shove and Walker, 2014; Warde, 2005), consumption occurs as people accomplish meaningful activities such as feeding themselves, making their way to work or social activity and so forth. At the same time, consumption can also have a more specific meaning. For instance, in Article I, consumption refers to consumption expenditure as a means to access or obtain tangible items or services needed in doings. Further, consumption can also refer to the consumption of resources such as energy (e.g., Article IV) or perishable items such as food (Article II). Section 2.3 elaborates on the understanding of consumption in this dissertation in more detail.

The dissertation consists of five articles briefly introduced below.

Article I presents an econometric analysis of household consumption expenditure and derived carbon footprints in Finland. The article identifies and discusses drivers of carbon footprints including income, socio-economic and spatial variables. The study shows and underlines how high-resolution data and modelling are required to describe the differences of consumption based on large datasets in order to identify, for example, place-specific aspects of consumption, and inform policy making. The analysis also joins the body of literature showing the prominent role of income as a driver of expenditure and footprints, meanwhile remaining cautious about the potential of decoupling footprints from the volume of consumption.

Article II studies nudging and attentive experimentation as a means to advance sustainable eating, especially plant and sustainable fish-based meals, at a workplace restaurant. Long-term monitoring (four consecutive years) of food item use and carbon footprint estimations of food is used to track changes in the food served and used to guide the experiment during the process. The collected data are used in communication and discussions with the customers and restaurant personnel.

Article III examines carbon footprint calculators for citizens, specifically their features and uses in initiatives to steer household consumption in the context of affluent countries. Data consist of systematic analysis of calculators and expert interviews with calculator developers. The interview data reveal experiences of calculator use pointing to experienced challenges and success in their use. Practice theory framework is used to reframe findings on expectations and experiences with calculators to engage people to use them and steer their consumption accordingly.

Article IV presents a literature review of qualitative studies on smart metering of energy and water in homes and discusses the findings in relation to European survey data. It uses practice theory concepts to reframe the earlier findings in studies and experiments of smart metering to provide a novel perspective on the challenges and potential of smart metering to reduce energy and water consumption in homes.

Article V summarises and analyses experiences from a research project developing action models to enhance environmentally more sustainable household consumption. The action models developed and applied a collection of consumption-based data, translating them into communicable figures and information that would support meaningful actions. The article highlights the role of intermediaries in supporting the use of tailored data and tools as well as in making the numbers and figures meaningful for people and the context.

2 THEORETICAL FRAMEWORK

This chapter introduces the research approaches which the dissertation builds upon and aims to bridge. First, Section 2.1 provides an overview of policy instruments on sustainable (household) consumption and the debate on the type of transformation required. Section 2.2 then introduces the practice theory perspective on household consumption and steering attempts. Section 2.3 presents a consumption-based approach to measuring the environmental impacts of household consumption, and empirical as well as methodological discussions of practical applications, focusing mainly on carbon footprint calculators.

2.1 POLICIES TO STEER CONSUMPTION

In this section, I present an overview of the academic literature on policies of sustainable consumption and production. The focus is on the first two decades of the 2000s to approach the empirical material of this dissertation through the perspective of timely academic policy discussions. The purpose is to introduce the types of policy instruments in order to position the measures used in the cases studied. I also address how the emphasis of sufficiency or efficiency approaches – that is, stressing either the volume of consumption or exploring the means to deliver the same products and services but with less impact – is present in discussions on sustainable consumption and production. The type of instruments and chosen position are essential for my analysis as they may affect implicit expectations of consumption changes, and the mechanisms to deliver changes. I adopt a systemic perspective on consumption and production instead of focusing only on the decisions and motivations of consumers.

To position applications and initiatives studied in this thesis, I introduce a framework of sustainable consumption policy measures. Wolff and Schönherr (2011) differentiate four categories of such instruments:

1. Regulatory instruments such as standards, prohibitions and limits;
2. Economic instruments including subsidies, taxes, trading schemes, compensations and public procurement;
3. Communicative instruments, which can be voluntary or mandatory product information and a variety of other communicative instruments related to information provision, campaigns and advisory activities;
4. Procedural instruments and societal self-regulation covering various measures such as infrastructure provision, voluntary agreements and corporate social responsibility schemes.

Wolff and Schönherr (ibid.) introduced the classification for policy evaluation purposes, a practical goal that also makes it useful for this dissertation. Labelling the measures in the studied initiatives according to the above-listed categories clarifies the intended mechanisms of the studied steering measures.

In the field of GHG accounting and policies, scholars have reviewed and categorised accounting procedures for input-output and life-cycle GHG emissions (Kokoni and Skea, 2014), and policy recommendations (Ottelin et al., 2019). The categorisation of policy instruments presented by Kokoni and Skea (2014) differentiates between soft and hard applications and mentions examples of proposed as well as implemented procedures. Measures listed in the soft measures – that is, voluntary, with the role of informing decision-making – are in line with communicative and procedural instruments listed by Wolff and Schönherr. Hard applications include regulatory and economic instruments. The categorisation mentioned above are used later to discuss the studied steering initiatives.

In addition to mapping policies of sustainable consumption (and production), it is underlined that policies exist within a wider policy framework (Wolff and Schönherr, 2011); other policies may have conflicting aims or outcomes (Christensen et al., 2007; Heiskanen and Laakso, 2019) compared with sustainable consumption policies. For instance, although forerunner countries such as Sweden have recognised and aim to tackle consumption-based GHG emissions, putting in place ambitious measures to steer consumption is tricky (Isenhour and Feng, 2016). In this respect, it has been argued that soft, informational and voluntary measures are easier to implement due to relatively low resistance and conflict compared to more stringent hard measures (Heiskanen et al., 2014; see also Whitmarsh, 2009).

The issue of lower resistance is also found in analysis of low-energy policies in the UK and Finland (Kivimaa and Kern, 2016). The study by Kivimaa and Kern (ibid.) suggests that policies supporting innovation are more prevalent than policies of 'creative destruction' destabilising the incumbent unsustainable systems. The means and scope to steer is important, especially in light of overly positive expectations of policies based on information provision (Heiskanen et al., 2014) and the power of supporting innovation compared to the stable position of incumbent systems (Kivimaa and Kern ibid.).

Addressing consumption is a matter of also incorporating measures to steer supply in policy mixes (Ivanova et al., 2020; Moberg et al., 2019; Nissinen et al., 2015), along with direct communication and interaction with households to persuade them to instigate sustainable choices and behaviour change (Moloney and Strengers, 2014). Policies on sustainable consumption and production (SCP) are often approached together (Tukker et al., 2008), which is logical, as production technologies not only determine the emissions per unit of goods and services but also shape the volume and patterns of consumption (Vliet et al., 2005). In other words, the goods and services available and affordable for consumption affect what kind of doings are

perceived as normal or as luxury, ideas which continue to evolve over time and space, and alongside changes in production and supply (Shove, 2003). In a similar line of thinking, Welch and Southerton (2019) differentiate between policies focusing on individual behaviour and on systemic change, and highlight how patterns of consumption emerge from and are embedded in the wider systems. Perceptions of normality and challenging them is also prevalent in the work of Tukker et al. (2008), who map the roles of government, business and NGOs in providing support, infrastructure and incentives for steering consumption. The framework by Tukker et al. also differentiates between measures to deal with issues that do or do not clash with current mainstream perceptions of standards of normal life. The standards are linked to the discussion on sufficient levels of comfort and which aspects are non-negotiable, calling for meeting the demand but more efficiently and with fewer negative impacts.

National policy programmes provide examples of advancing sustainable consumption and production. Analysis of policy programmes on SCP, including Finland, suggests that even countries with pioneering SCP policies tend to focus on efficiency of supply rather than sufficiency (Berg, 2011). Berg also highlights the risk of outsourcing responsibility for unsustainability to consumers, non-governmental organisations, and businesses which do not have the required mandate or resources to take the initiative. High expectations of 'green consumerism' to tackle unsustainability of consumption has been accused of constituting consumer scapegoatism (Akenji, 2014). While voluntary measures are found acceptable, their potential to contribute to ambitious climate targets may be limited (Moberg et al., 2019). The outsourcing of responsibility, and high expectations that voluntary and active behaviour change will attain absolute reduction of environmental impacts, may reflect the neglected role of power dynamics (Fuchs et al., 2016).

There are policies in place to regulate the types of products and services that have access to the market (Wahlen, 2009). An example of a combination of regulations and information is the energy labelling of white goods. Studies such as Boyano et al. (2019) on washing machines suggest that, while energy-labelling schemes have been successful in improving the energy efficiency of washing cycles and energy consumption per kg of capacity, the savings are compromised by use practices. The above mentioned labelling scheme is an example of how environmental governance and policies advance technical improvements in efficiency. At the same time, from a sufficiency perspective, there has been little success in tackling the growth in consumption levels and the ratcheting standards of cleanliness, for instance (Shove, 2003). In other words, despite improvements in efficiency levels, required changes in the levels and patterns of consumption (Fuchs and Lorek, 2005) lag behind.

Statistics combined with emission data reveal the consequences of growing consumption. Economy-wide analysis of Finland suggests that efficiency improvements have likely contributed to curbing the growth of consumption-based GHG emissions from household expenditure despite a growing volume

of consumption (Savolainen et al., 2019a). When consumption expenditure has a higher growth rate than its related GHG emissions, the trend can be labelled as relative decoupling.[2] Nevertheless, the Finnish data does not show a decreasing trend in absolute consumption-based household-expenditure GHG emissions. On the other hand, a Swedish study shows a declining trend of consumption-based, household GHG emissions for the years 2008–2014 and even the absolute decoupling of economic growth and consumption-based emissions (Palm et al., 2019). At the same time, another Swedish study showed the shift of consumption-based GHG emissions from domestic direct emissions to sources outside Sweden due to imported goods (Schmidt et al., 2019).

Despite advances in technologies and policies to tackle emissions and increase efficiency of production, and promising examples such as the Swedish case, various environmental indicators remain alarming (Steffen et al., 2015). Furthermore, evidence of the decoupling of economic growth and emissions from a consumption-based perspective over larger areas and extended periods of time is lacking (Parrique et al., 2019). Hence, some scholars such as O'Rourke and Lollo (2015) remain sceptical about whether efficiency improvements alone will beat the trend of growing environmental impacts from consumption. Taking this further, Wiedmann et al. (2020) summarise proposed approaches to sustainable prosperity that take a range of stances in terms of, for example, economic growth, volume of consumption, and institutions.

The emphasis on efficiency in tackling environmental problems of production-consumption systems and consumers' roles in adopting new, improved products and services is also prevalent in circular economy discussions (e.g., Ellen MacArthur Foundation, 2013).[3] The concept has attracted the attention of businesses and policymakers in order to approach the problems of the so-called linear economy (Ghisellini et al., 2016; Murray et al., 2017). Meanwhile, the notion of a circular economy leaves space for several, even conflicting, interpretations and agendas. While some studies found support for a decrease in volumes and sufficiency perspectives (Tunn et al., 2019), the technological fixes – focusing on recycling, closing material loops and shifts in business models from ownership to access and services – seem to dominate over discussions questioning current consumption patterns

[2] Defined in (IRP, 2017) p.7, "Decoupling is when resource use or some environmental pressure either grows at a slower rate than the economic activity that is causing it."

[3] Several authors and organisations have conceptualised their own definitions and interpretations of a circular economy (Kirchherr et al., 2017) although the details of the debate on definition is beyond the scope of this dissertation. Hence, a widely cited definition of Ellen MacArthur Foundation (2013) p.7 is used here: "A circular economy is an industrial system that is restorative or regenerative by intention and design… It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models."

(Schulz et al., 2019). Efficiency and low-carbon perspectives also dominate The Green Deal (European Commission, 2019), although financial instruments such as carbon pricing are also listed.

The role of consumers is described in the circular economy literature as changing from owners to users through forms of collaborative consumption and a shift towards product-service systems (Schulz et al., 2019; Tukker, 2015). Hence, consumer acceptance and informed choices (e.g., Ghisellini et al., 2016) are seen as important in advancing a circular economy. The idea of responsible consumer choice resonates with the findings of Camacho-Otero et al. (2018), and a study analysing consumer policy discourses (Wahlen, 2009).

I interpret the varying emphasis on the role of efficiency and sufficiency to mean that recognising and making the chosen position regarding the two approaches explicit should be part of the discussion and roles of data-based applications. Further, the argument of Geels et al. (2015) on how to move beyond the dualist discussion on efficiency / sufficiency is relevant. The article by Geels et al. proposes reconfiguration, focusing on socio-technical systems and everyday practices. The suggestion resonates with the previous argument by Spaargaren and Oosterveer (2010) on appropriation and provision of environmental innovations, and with Shove and Walker's work (2010) on the importance of understanding the dynamics of demand, referring to drivers beyond the individual motivations and decisions stressed by the widely applied theory of planned behaviour (Ajzen, 1991).

The dynamics of demand should be considered in addition to an innovation-centred approach to socio-technical transitions which, Shove and Walker (2010) argue, focuses on supply without problematising demand. The demand for resources, services, goods and so on is made, not only met, and policies have a role to play in shaping it (Rinkinen et al., 2020). In their review of sustainability transition research, Köhler et al. (2019) outline the characteristics of sustainability, highlighting the themes of the co-evolution of technologies and user practices, multi-actor processes and the question of stability and change, as well as disagreement (e.g., on the desired path of transition), all of which resonate with the issues discussed in this section. Köhler et al. (ibid.) also list themes connected with long-term processes: the development of innovations, uncertainty about how changes occur and normative directionality, which refers to the limited incentives for businesses to change if supportive public policy and regulations are not in place. Ultimately, the literature indicates an emerging and growing interest in exploring the dynamics and mechanisms of changes in doings and consumption.

2.2 HOUSEHOLD CONSUMPTION AND PRACTICE THEORY

As consumption is one of the central concepts of this thesis, it needs to be underlined that practice theory pinpoints that consumption is not a practice; rather, most practices entail consumption (Warde, 2005). Consumption, according to Røpke (2009, p. 2495) captures "the appropriation and transformation of resources in relation to domestic practices". Therefore, consumption and derived carbon footprints are outcomes of almost every practice. While consumption, as such, is not the core subject in practice theory research, I will continue to refer to consumption along with practices in this thesis.

In addition to consumption, practice is a central concept in this study due to the choice to interpret consumption through the practice theory framework. A frequently cited definition (Reckwitz, 2002, p. 249) describes practice as

> a routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge.

In this dissertation, I use the phrase 'everyday doings' in parallel with practices, while Røpke (2009) refers to practices as 'everyday life'. Unpacking the tangible and intangible building blocks of practices, or everyday doings, are further concretised later in this section by using the conceptualisation presented in Shove et al. (2012).

There is a growing number of empirical research contributions applying practice theory in fields that are relevant to household consumption. These include: energy (Royston et al., 2018; Shove, 2017a; Strengers, 2012); underlying infrastructures of provision (Shove and Trentmann, 2019; Vliet et al., 2005); smart technologies and homes (Naus et al., 2014; Smale et al., 2017; Strengers, 2013); food (Rinkinen et al., 2017; Warde, 2016); mobilities (Laakso, 2017; Mattioli et al., 2016; Sopjani et al., 2020; Spotswood et al., 2015); and tourism (Lamers et al., 2017; Luzecka, 2016). As listed above, considerable empirical research drawing on practice theory has been conducted on the everyday or ordinary (Gronow and Warde, 2001) (domestic) life. In addition, Watson et al. (2020) introduce a practice-based approach to inform policy and practical initiatives on people's everyday resource use.

The motivation for the turn to theories of practice may be related to how practice theory is often being presented as being different from more prevalent psychological, behavioural, economic, or cultural approaches to consumption (Halkier and Jensen, 2011; Keller et al., 2016; Shove, 2010; Spaargaren, 2011; Warde, 2014) and derived mainstream forms of climate policy (Shove, 2014a). While the number of studies applying practice theory has grown, the prevalence of research traditions mentioned above is illustrated in a cross-

disciplinary review of what influences consumption (Poças Ribeiro et al., 2019), as well as in current policies (Hampton and Adams, 2018; Shove, 2014b).

Scholars writing in the field of environmental psychology have noted that good intentions do not always turn into actions, and examining this attitude-intention-behaviour-gap (e.g., Carrington et al., 2010), recognises that external or situational factors affect environmental behaviour change; some conceptualisations of behaviour also adopt a systemic perspective, taking into consideration the role of the environment and human interactions with it (e.g., Kaaronen, 2017). Meanwhile, authors such as Whitmarsh et al. (2011) point out that merely raising awareness – specifically, of levels of carbon capability in this instance – is not sufficient to overcome the value-action gap, as even informed or motivated people do not change their doings at the scale required. Barriers and issues with systems of provision are considered to play a role in this.

It has been recognised in the field of sustainable consumption that practice theory supports overcoming the dualistic positions of relying on *either* individualist *or* systemic explanations (Spaargaren, 2011), and shifts the focus from individual characteristics, motivations or behaviour change to socially shared and materially rooted practices. Also important to steering sustainable consumption also is that "[p]ractices are motivated by core concerns in everyday life, and people take a strong interest in being competent practitioners" (Røpke, 2009, p. 2496); Røpke adds that "environmental considerations may easily conflict with other concerns", which has implications for steering attempts. Being a competent practitioner is not only about (environmental and sustainability) knowledge and values, as negotiating and solving conflicts are rooted in the materiality of our everyday environment.

As this dissertation seeks to look beyond the informational characteristics and mechanisms of data-based tools and steering, I adopt practice theory thinking and concepts to direct attention towards material and social linkages and frictions between data and tools and everyday activities. My decision to choose practice theory as the sensitising tool for this dissertation relies on the systemic perspective it provides onto how everyday doings and related consumption patterns emerge, persist, transform and are abandoned. I find that Nicolini's (2017) interpretation of the 'conflict-sensitive orientation' of practice theory describes my attempt to understand the success of, and challenges to, steering practices. The orientation is described by Nicolini as focusing on the co-evolution, conflict and interference of practices.

This dissertation adopts the interpretation of Shove et al. (2012) on the elements of practices. Three main categories are distinguished: firstly, material elements, referring to tangible objects used in practices such as cars and underlying physical infrastructure (Shove and Trentmann, 2019) like road networks. Secondly, meanings refer to shared and personal ideas on what is perceived as normal, desirable, safe, convenient and comfortable. For

instance, it may be commonly perceived as safer to drive kids to school in contrast to letting them walk. The third element is competences, including the cognitive and physical abilities and learned skills to navigate a car through traffic. As the example illustrates, practices develop through, and are shaped by, interconnections of elements. Automobility in its current form only exists for those that have access to vehicles and infrastructure, perceive driving as a desired or at least necessary form of mobility to undertake everyday activities and have the required competencies (or a driver).

Mobility illustrates how practices are connected (Shove et al., 2012) and, therefore, also influence one another, and that infrastructure plays an important role in the development of practices (Shove et al., 2015). For instance, daily driving patterns are the very concrete form of a connecting practice to manage and fit together different doings (Sopjani et al., 2020), and certain practices i.e., travel purposes, such as escorting children and shopping, are more car dependent than others (Mattioli et al., 2016). In addition to having access to automobility and the perceived comfort of driving, there might be a lock-in (Ivanova et al., 2018) to driving due to time use patterns, for instance (see also Shove and Walker, 2010 for discussion on how the introduction of the London congestion charge scheme affected the "timespaces" of everyday activities). As highlighted by Røpke (2009), practices compete for time and, therefore, adopting one practice often means that another one must give way. Moreover, taken-for-granted standards are challenging to reverse and transform due to connections between practices that shape each other. In other words, it may be easier to add more activities to one's daily schedule as faster modes of transport enable their inclusion by 'saving time', than to reverse the pattern and abandon certain activities due to the decision to employ a slower means of transport.

An article by Watson (2012) shows how practices are shaped by place- and context-specific development trajectories. Watson discusses the possibilities of applying the practice theory approach to study systemic change, using the example of auto- and velomobilities as socio-technical systems and arenas for intervention and the rearrangement of practices. The article looks at everyday mobilities and discusses how policies and decision-making shape the transport system, and how these processes are influenced by the histories and current state of developments.

To reflect on the mobility illustrations above, practice theory recognises that people have the agency to participate, repeat, transform or abandon a certain practice and, therefore, are not perceived to be bound deterministically by the structural circumstances (Røpke, 2009). At the same time, it is recognised that consumption and everyday doings are shaped by infrastructure, urban form (Wiedenhofer et al., 2018), the time dimension (Druckman et al., 2012; Jalas and Juntunen, 2015; Smetschka et al., 2019), and, for instance, the perceived abundance or scarcity of energy and water (Strengers and Maller, 2012). However, household routines and practices that manage everyday activities in similar settings can vary greatly from one to

another (Gram-Hanssen, 2008), which has impacts on environmental outcomes. Taking stock of the expertise of people and communities, Jalas et al. (2017) suggest experimentation as a potential means of enrolling people in sustainability transitions.

At this point, it is important to underline that certain elements are prerequisites of realising specific forms of practices; however, their existence does not guarantee that a certain form of practice will emerge. Often, technologies with, for example, energy saving potential can be used in such a manner that the full potential is not realised, as Gram-Hanssen et al. (2017) discuss in case of heat pumps. An empirical study by Cherunya et al. (2020) uses data on sanitation and toileting practices in informal urban settlements in Nairobi to develop a theoretical and conceptual contribution to the challenges of embedding new solutions to replace inferior practices. While the empirical context is very different from the affluent societies of this dissertation, the work of Cherunya and colleagues provides applicable theoretical perspectives: the first is to distinguish processes concerned with the acceptance and embedding of innovations; the second is to identify the elements of practice which are preconditions for adopting an innovation and related practice while, at the same time, recognising how the complexity of everyday life may hinder the embedding of even accepted and superior solutions. As the Cherunya et al. study shows, money also limits or grants access to certain elements, and forms of practices and related consumption (see also Article I).

The argument resonates with the circular economy work of Camacho-Otero et al. (2018, p. 19), which asserts that "change is not only about acceptance; it is also about actual adoption and diffusion, requiring research on not only products and services, but also on the system level". The sequential nature of practices in everyday life and the dimension of time are also recognised in the practice literature (Hand et al., 2005; Shove et al., 2012) as shaping doings, and in sustainable consumption studies (e.g., Druckman et al., 2012; Heinonen et al., 2013; Jalas and Juntunen, 2015; Smetschka et al., 2019).

Another key aspect of the practice theory approach is the notion of escalating standards in terms of, for instance, norms of comfort and cleanliness (Nicholls and Strengers, 2019; Shove, 2003). This acknowledges how practices evolve, but also that such changes generally take more resource- or carbon-intensive directions. This issue is important as there are expectations that energy efficiency (Shove, 2017a) or smart home technologies (Strengers and Nicholls, 2017) should lead to reduced environmental impacts (see also Article IV). In economics, the concept of rebound (e.g., Chitnis et al., 2013) is used to describe how, for instance, savings from energy efficiency are partly offset by increasing consumption of the more efficient product or other products. While improving efficiency is needed to mitigate GHG emissions, rebound and systemic changes brought about by greater abundance or a more affordable supply are problematic if growing consumption offsets the positive development. On a household level, a study by Christensen et al. (2007)

suggested that people may be more willing to invest resources in improving the standard of their homes rather than improving the energy efficiency without raising the current level of comfort, available space and facilities. To take an example from transport, based on Finnish data, the benefits of not owning a car and thus driving less may be offset by flying more (Ottelin et al., 2017).

Drawing on the practice theory perspective introduced above, and directing the focus back to household consumption as interpreted in this dissertation, Figure 1 illustrates the understanding of the dynamics on which I build. Consumption in the core refers to the numerical outcomes that can be recorded, measured or estimated and which can be used to communicate environmental impacts and to distinguish small contributions from large ones. Everyday doings refer to the forms of meaningful practices in which people participate in their lives. Meaningful does not necessitate that every action, as such, is meaningful but rather that doings have a meaningful purpose such as the enjoyment of a meal or taking care of other people. The outmost circle in the figure concretises the elements of practice, following the conceptualisation of Shove et al. (2012). The aim is to examine the numerical figures of consumption from the perspective of dynamic interactions shaping everyday doings and, therefore, affecting footprints.

As examples in Figure 1 illustrate, practices are often mundane or ordinary (Gronow and Warde, 2001), which helps to turn the focus away from exceptional, luxurious activities into the footprints of ordinary daily life: keeping oneself warm, fed, and going from one place to another.

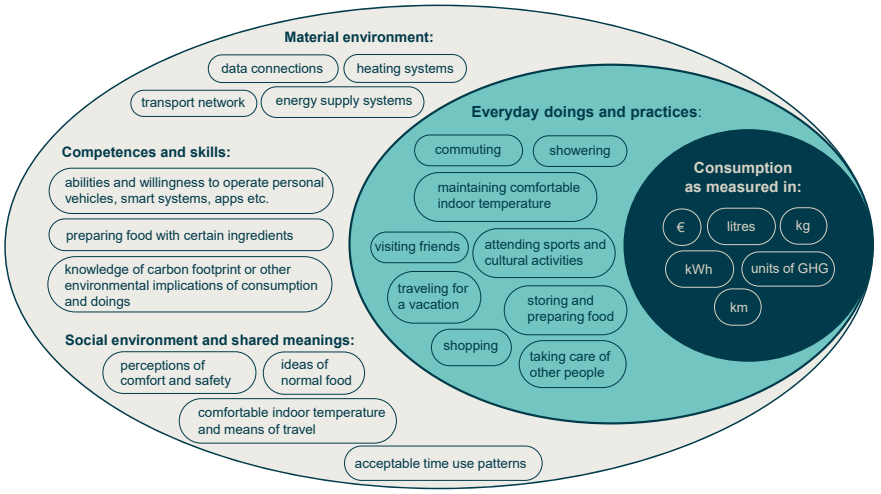

Figure 1. Consumption, everyday doings and elements of practices as interpreted in this dissertation. Examples of practice elements, meaningful everyday doings and units of consumption are listed for illustrative purposes.

In this dissertation, practice theory is used as a sensitising device (see further discussion in Section 3.2) to reveal and discuss the potentials, tensions and resistance arising from the use of metering and footprinting household consumption. In other words, practice thinking provides conceptual tools for the critical assessment of experiences of using consumption data and applications such as carbon footprint calculators (Articles II, III, and V) and smart metering (Article IV) to inform users of the impacts of their consumption and to steer them.

2.3 STEERING CONSUMPTION WITH DATA AND FOOTPRINTS

In this section, I introduce research on applications such as carbon footprint calculators to track, communicate and provide advice on household consumption. I also briefly present previous findings on how and why consumption-based carbon footprints vary among households and populations. My purpose is to provide an overview of the critique and empirical experiences of data and data-based applications in steering consumption.

While there are several indicators of resource, energy and water use, as well as types of environmental footprints, this section focuses mainly on carbon footprints and metering consumption contributing to them. Thus, the carbon footprint is used as an example of an environmental indicator in steering consumption. The technical and methodological details of how carbon footprints or other environmental impacts are estimated are beyond the scope of this dissertation. Still, a general understanding is beneficial as characteristics of inputs and outputs guide and limit conclusions and suggestions based on metering and footprinting.

I begin by taking a step back from footprints to highlight that the tangible link between consumption of electricity, water, manufactured goods or food items and related environmental consequences, is missing from everyday life as a result of geographically disconnected production and consumption. It has been argued that people no longer know, or have few reasons to know, how much energy and water they consume as modern systems of supply and distribution are designed to enable constant access to resources such as energy and water (Moloney and Strengers, 2014). Therefore, technologies and interfaces to access consumption data, such as smart metering of energy consumption, have been suggested in order to re-establish the link (Burgess and Nye, 2008; Strengers, 2011). The connection could mean the provision of tailored feedback based on household, person or practice-specific data. Data could be used to communicate orders of magnitude such as comparisons with averages or sustainable levels of consumption, or to distinguish major sources of consumption to be tackled. Empirical evidence indicates, however, that

making energy consumption visible may not be a silver bullet to change consumption patterns (Hargreaves et al., 2013).

Technical advances to measure, track, process and share data on consumption, combined with methodologies to estimate carbon footprints and widespread access to online and mobile tools, provide novel means to track consumption and derived footprints. For instance, the roll-out of smart electricity meters in the EU (Directive 2009/72/EC, 2009) provides opportunities for the development of informational measures (Article IV) and pricing models aiming to steer household electricity consumption. Further, a number of studies and communication and for-profit initiatives have introduced online tools and smartphone apps for monitoring consumption, which are aimed at informing users and steering consumption and derived carbon footprints (e.g., Articles III and V).

The foundations for translating consumption into carbon footprints rest on methodologies for analysing emissions and resource use throughout production chains and within the context of global trade (e.g., Hertwich and Peters, 2009; Wiedmann and Lenzen, 2018). The consumption-based approach takes into account the embedded emissions of consumed goods regardless of their geographical origin (Kokoni and Skea, 2014) and, therefore, tackles displaced patterns of production and consumption (Harris et al., 2012; Kanemoto et al., 2014).

Environmentally extended input-output (EEIO) analysis (Minx et al., 2009), relying on standardised statistic data sources, has shown differences in per capita carbon footprints between countries (Hertwich and Peters, 2009) and sub-national populations (Wiedenhofer et al., 2017), as well as burden-shifting across countries (Wiedmann and Lenzen, 2018). Analyses also illustrate the sources of carbon emissions by product category: for instance, housing, travel, food and other goods and services (Girod et al., 2014).

An important contribution of an EEIO analysis is to illustrate how unsustainable carbon footprints are derived largely from what has been regarded as normal and ordinary middle-class consumption in affluent countries and populations. Analysis of national and multiregional systems of production and consumption also provide valuable input data for footprint calculation applications in the form of GHG intensities per unit of expenditure. Moreover, the methodology also allows footprint change to be modelled based on expected shifts of consumption patterns in certain directions, in other words, depending on the types of goods and services consumed (e.g., Girod et al., 2014; Tukker et al., 2011; Wood et al., 2017). The general limitations of EEIO are discussed in Article I (see also Tukker et al., 2018 for shortcomings and potential developments on multiregional input-output analysis). At this point it is important to highlight the well-known limitation that while EEIO is able to distinguish GHG intensities between commodities such as food items, housing, energy and different transport services, within each commodity the emission intensity represents an average good or service. While the number of different commodities and thus the level of detail captured by the method is

increasing, the practical implication is that the footprint for a consumer choosing low-emission or impact goods from the market may be overestimated when EEIO emission intensities representing average commodities are used.

The GHG intensities per unit of expenditure allow estimations of carbon footprints based on survey data such as Household Budget Surveys (see Article I and e.g., Ala-Mantila et al., 2016; Christis et al., 2019; Froemelt et al., 2018; Gill and Moeller, 2018; Heinonen et al., 2013; Ottelin et al., 2018). Survey data enables the analysis of the drivers of carbon footprints. Income, number and age of household members, education, socioeconomic factors and residential location have been identified as the principal explanatory variables in econometric analysis of household consumption carbon footprints (Article I; Druckman and Jackson, 2016; Ivanova et al., 2017; Rosa and Dietz, 2012; Zhang et al., 2015). A review of carbon footprints and their drivers by Wiedenhofer et al. (2018) suggests that the urban environment along with societal arrangements influence time use and patterns of consumption.

Meanwhile, studies including environmental values have shown that attitudes have little or no effect on carbon (Moser and Kleinhückelkotten, 2018; Nässén et al., 2015) or ecological (Csutora, 2012) footprints of respondents. Interestingly, however, a study on grassroots initiatives to decrease consumption carbon footprints (Vita et al., 2020) showed that participants had smaller footprints compared to the control group and that the significance of income as a driver of footprint size decreased among initiative participants.

An article on modelling lifestyle changes and integrating them with wider models (van den Berg et al., 2019) illustrates the complexities and interconnections of consumption and doings. While the mapping of van den Berg et al. aims to advance the modelling of lifestyle changes, the analysis is also relevant for the development of data-based steering measures as the conceptualisations make explicit distinctions between types of measures (by consumption area and in terms of mechanism) and their connections.

Having introduced the findings of research on drivers of, and variation in, household carbon footprints, I return to how calculations and estimations are used in applications. Carbon footprint calculation methodologies,[4] combined with improved access to accurate consumption data, internet, smartphones and almost real-time consumption figures, have provided novel means to develop the tracking of consumption and turning the figures into carbon footprints. In addition to presenting current figures and changes, applications

[4] See Heinonen et al. (2020) for a review and discussion on variation within the field of EEIO analysis. Further, calculators and illustrations can also rely on other methodologies such as Life Cycle Assessment, which focuses on analyses and comparisons at a product level (e.g., Hertwich, 2011; Nissinen et al., 2007). For a more extensive overview of household carbon footprinting methods, see a review by Zhang et al. (2015).

can also suggest tailored actions based on the current pattern of consumption and footprint (Nahar and Verma, 2018; West et al., 2016).

In parallel with the introduction of footprint calculators for the public, studies assessing them have emerged. Papers have critically assessed and compared calculation methodologies used in, but not necessarily limited to, carbon footprint calculators (Birnik, 2013; Čuček et al., 2012; Padgett et al., 2008; Rahman et al., 2011); described the calculation procedures of specific applications (Andersson, 2020; Nahar and Verma, 2018); discussed calculators' focus or coverage (Kim and Neff, 2009) and their usability and ways of communication (Kim and Neff, 2009; Mulrow et al., 2019; Rahman et al., 2011; West et al., 2016); stated preferences of potential users of the calculator applications (Chatterton et al., 2009; Rahman et al., 2011); and examined their use in empirical studies in changing household consumption (West et al., 2016).

While some authors refrain from taking a stance on the type of agency that calculators and other sustainability apps assign to people, Fuentes and Sörum (2018) highlight how apps can reinforce the individualisation of responsibility, and Gram-Hanssen and Christensen (2012) call for engaging people in collective actions a side from personal actions. Further, some authors (Čuček et al., 2012; Matuštík and Kočí, 2019) conclude that the research findings on footprints should feed into policymaking in addition to promoting sustainable lifestyles. Minx et al. (2009) also highlight how consumption-based carbon footprint data, not necessarily limited to personalised applications, can indicate hotspots and track progress. They underline that changes in lifestyles and consumer behaviour are required as technological change alone is unlikely to be sufficient to deliver a satisfactory reduction in emissions.

To summarise, the studies introduced above highlight the valuable contributions made by methodologies and applications targeting household consumption from an environmental perspective. At the same time, the process of steering consumption with data-based measures and applications, and their role in sustainable consumption policy, remains inconclusive. This resonates with the review by Ottelin et al. (2019) on the policy implications of carbon footprints, which shows that the majority of consumption-based carbon footprint studies recognise the importance of changing consumption patterns and illustrate the outcomes of changed patterns. Fewer studies, however, contribute to the discussion of how the changes can be realised.

3 DATA AND METHODS

This section provides an overview of the research material and methods used in the dissertation. Section 3.1 summarises the data and presents the combination of quantitative and qualitative research approaches used; Section 3.2 explicates how practice theory is applied as a sensitising device to interpret results and reframe previous findings; and lastly, Section 3.3 critically reflects on the research design of the study.

3.1 SUMMARY OF THE RESEARCH MATERIAL

The research subject – using consumption data to steer household consumption – calls for an understanding of how consumption can be measured and translated into environmental measures such as carbon footprints; meanwhile, the steering dimension requires sensitivity to material and social elements, and expected steering mechanisms. Therefore, this dissertation combines quantitative and qualitative research approaches in order to focus on areas of consumption making significant contributions to household carbon footprints, while applying qualitative methods to capture the complexities of the everyday. Methods and data are summarised in Table 1 and discussed in brief below the table. A more detailed description of data and methods is presented in each of the research articles.

Quantitative methods are used to estimate household carbon footprints and their drivers from data provided by a national Household Budget Survey (Article I), and in applied approaches to assess the carbon footprints of households (Article V) and a restaurant's food serving operations (Article II). Qualitative methods focus on the experiences and expectations of intermediaries and professionals (Articles II–V), as well as public audience (Articles II and V), in taking up and using consumption-based data and footprinting activities – and changing their doings as a result. The richness of data from several initiatives contributes to understanding steering activities in real-life settings.

Table 1. Summary of the research material.

Quantitative methods and data				
Article I	**Article II**	**Article III**	**Article IV**	**Article V**
Econometric analysis of household consumption expenditure and carbon footprints in Finland. Household Budget Survey 2016 (N=3,490).	Food item data, estimation of carbon footprints and cash register data from one restaurant, four consecutive years. Survey for restaurant customers (N=170).			Tracking (metered and self-reported figures) of household consumption data and carbon footprint estimations for pilot households and housing companies.
Qualitative methods and data				
Article I	**Article II**	**Article III**	**Article IV**	**Article V**
	Focus group discussions with customers (four discussions, altogether 24 participants), and with restaurant personnel and corporate representatives (three sessions, altogether 10 participants).	Six semi-structured expert interviews with carbon footprint calculator developers. Systematic analysis of 10 carbon footprint calculators and supplementary materials.	Integrative literature review (20 articles) and survey for European organisations with experience in smart metering projects (11 responses).	Participatory action research 1) Renovation and housing management professionals. 2) Energy management in housing companies. 3) Tailored advice for households. 4) Online tools and face-to-face communication of sustainable choices.

Table 1 highlights how the data present household consumption from zoomed-out and zoomed-in perspectives. The expenditure data for Finnish households (Article I) shows how different areas of consumption (housing and energy, food, transport, tangible goods and services) and derived footprints vary among households. Data and analysis in Article I show the roles played by household income and other socio-economic, demographic and spatial characteristics as drivers of consumption patterns and carbon footprints. In other words, the economy-wide data contribute to knowledge of what needs steering and how consumption patterns differ among households. The

expenditure patterns and derived footprints paint a picture on the commodities – that is, bundles of products and services – of which the consumption patterns and footprints consist. Article I also discusses implications for policy design, recognising that the analysis reveals problems but calling for further and different types of work to design measures to tackle them.

Zooming in to everyday setting of applications and initiatives to steer consumption with qualitative approaches (Articles II–V) reveals whether applications and the tailored feedback are embedded in everyday practices, and the frictions involved in engaging with the applications and following feedback. The qualitative analysis taps into first and second-hand data from experts, intermediaries, application users and public audiences.

The qualitative material (Articles II–V) is drawn from several applications and related initiatives using automatically collected or self-reported consumption data. Data are, in most cases, translated into carbon footprint information and tailored feedback on how to decrease consumption or related negative environmental impacts. While the applications and data differ in their scope – areas of consumption, unit of measurement and type of use – the common denominator is that the underlying motivation is to steer consumption from the environmental perspective. More specifically, initiatives focus on steering doings and consumption rather than aiming to initiate new types of activities to offset impacts. An example of the latter is planting trees (Zhang et al., 2020) instead of tackling existing problematic practices.

However, the underlying environmental rationale does not need to be the sole purpose in making use of the studied applications and data. For instance, energy-saving (Articles III, IV, and V) or car choice (Article III) can also be argued to save money. In all, the applications included in the research material incorporate one or more of following features: person, household or practice-specific scope; consumption data based on measurements or self-reporting to reflect actual consumption patterns; consumption refers to expenditure, frequency of purchase, energy, housing characteristics, driving distances and type of vehicle or food items; provision of tailored results describing consumption or footprint profile, feedback and suggestions to decrease GHG emissions or underlying consumption.

3.2 PRACTICE THEORY AS A SENSITISING FRAMEWORK

Practice theory has informed this dissertation in terms of research design (Article II), reframing empirical findings (Articles II, III and IV), providing understanding of consumption and everyday doings (Section 2.2) and synthesising the results in this summary article of the thesis. While practice theory did not guide all data collection and original analysis, it has been used

as a sensitising framework (Reckwitz, 2002) to analyse and reframe attempts to steer household consumption.

An overview of existing empirical research drawing on practice theories shows that studies mainly focus on specific practices (see Section 2.2). This dissertation aims to apply practice thinking to study the more general dynamics of steering (household) consumption from the environmental perspective by using cases studies focusing on consumption-based data and carbon footprints. Elements of practices (materials, meanings and competences as introduced in Section 2.2) are used in Articles III and IV to explicate how applications track and measure consumption and seek to support steering attempts. The purpose of applying practice theory concepts and thinking is to extend the focus from the characteristics of the applications and their users to relations and (potential or missing) interactions with the world around them. A similar argument in support of looking beyond people and single solutions and barriers has previously been made by Hargreaves (2011) when studying pro-environmental behaviour change in the workplace, and Watson et al. (2020) in relation to reframing policy problems to identify their potential to change everyday resource-use patterns. From a steering point of view, this interpretation is important, as the main focus is on problematic practices, rather than identification of potentially more advanced solutions to communicate with individuals and persuade them to make changes (see e.g., Sunio and Schmöcker, 2017 on persuasive design).

To elaborate further on the role of practice thinking in this dissertation, I interpret steering from this perspective to consist of a process of transforming the elements of practices or the connections between existing elements, thus following Shove et al. (2012). Hence, while altering practitioners' meaning-making and skills can be an essential component of steering initiatives, steering involves a broader effort than merely persuading people in their personal lives or professional roles to transform or abandon practices, or adopt ways of doing things differently. My purpose is to identify how the elements around us, often taken for granted, may hinder the shifts towards more sustainable consumption which are the purpose of the applications and initiatives.

Applications tracking and providing feedback on consumption patterns can potentially be embedded as elements in (everyday) practices. But, from a practice perspective, what use is the interpretation of consumption patterns and drivers identified from a national household data (Article I)? The methodologies for collecting and analysing statistical data are very different from practice methodologies. Qualitative analyses contribute to revealing the dynamics of how consumption patterns emerge, persist and/or are abandoned. Yet the data and derived conclusions of large datasets paint a picture of outcomes, in the form of expenditure and carbon footprints, that are the result of living everyday life. In other words, the large datasets and EEIO analysis show hard evidence of the state of things in each population. Thus,

tackling currently problematic consumption patterns calls for both quantitative and qualitative research approaches.

Shove (2017b, p. 167) has called for the "re-reading of input-output models, particularly if these are used as methods of quantifying and characterising the 'responsibility' for carbon emissions". Apart from the discussion on where to assign responsibility for consumption-based GHG emissions, it remains unspecified what the re-reading would mean; moreover, Schulz et al. (2019) note that, despite the potential of practice theory, its resource-intensive and time-consuming methods remain a challenge. I interpret this to mean that exploring ways to apply practice theory to other types of data besides first-hand observations of single practices would be an important contribution. I take this as an inspiration when examining potential ways to interpret findings from large datasets and secondary data with practice thinking, reflecting on the implications for steering initiatives and policies in Section 4.3.

3.3 REFLECTIONS ON THE RESEARCH DESIGN

This section critically reflects on the research design and the limitations of the theoretical approaches and data used. First to be discussed are the methodological and data-related limitations, especially in terms of the role and challenges of quantitative materials and the geographical scope of the study. I then reflect on the implications of applying practice theory as a sensitising device when critically assessing the potential of data-based applications to contribute to the policies and steering of sustainable consumption.

Quantitative evidence is often called for to evaluate whether a certain initiative has been useful in changing consumption. Strengthening quantitative approaches to tracking realised changes is also a long-term challenge in studies aiming at actual changes in consumption patterns, as Qiu and Patwardhan (2018) argue in the case of residential energy efficiency studies. Article V discusses two important challenges to tracking consumption. First, setting up systems to collect data on consumption (in households) can be costly if data cannot be drawn from existing data sources, although automatised and integrated data collection are likely to improve and ease this issue. Another challenge lies in identifying reasons why consumption patterns might have changed, as these may occur for a number of reasons related to life phases or external conditions and are not always due to steering efforts.

There are similar issues with regard to footprint-calculator use and impact. While a calculator can track footprint change over time if the user provides the input data, it is not easy to assert whether deviations are based on actual change or, for instance, are due to variation in rough estimations of consumption patterns. The issue is especially relevant in the case of applications relying on self-reported patterns of consumption. Article II illustrates the value of long-term follow-up (four consecutive years in this case)

and the possibilities it provides to reflect on how changes in food service have contributed to changes in lunch purchase patterns.

More extensive quantitative follow-up data could strengthen case studies such as those in Articles III and V. Nevertheless, the focus of this dissertation is to gain a tentative understanding of the mechanisms of how – rather than only if – consumption data and footprints can steer consumption and contribute to sustainable consumption policies. The strength of the qualitative approach is that it enables investigation of how consumption data and feedback are integrated into everyday doings and the mechanisms involved, whether or not change resulted – and why. On the other hand, a limitation of qualitative approaches is the lack of generalisability of the findings in larger populations. Thus, contributions using extensive quantitative data and research approaches would strengthen future analysis on the topic.

Despite the limitations, I argue that the focus of this study – the dynamics of consumption and resulting changes – is not compromised by limited possibilities to draw on quantitative evidence of how initiatives changed consumption. However, the number of expert informants, participants and households also have implications for the generalisation of the results.

The geographical scope of this study and its data – mainly from Finland and other Nordic countries – also require attention. Data in Articles I, II, and V are collected from Finland. Article III draws on data mostly from the Nordic countries including Finland, Sweden, Norway, Denmark and Iceland but also includes two footprint calculators designed and used outside Nordic countries: one in the UK and another aiming to reach a global audience. Article IV relies on a literature review, which is not limited to any specific region; however, the data are drawn from smart metering in an affluent country context.

The context is important when interpreting results and assessing their transferability potential. Practice theory literature highlights that practice arrangements vary and are context-specific even when studying similar material elements (see e.g., Rinkinen et al., 2017). For instance, political, welfare, energy, transport – and all the other systems that shape everyday life – have nation-specific and local characteristics; social norms also vary. The issue becomes very concrete when footprint calculators are modified to reach audiences from more than one country (Salo and Mattinen, 2017). While in empirical studies, applications and policy design must draw on and be embedded to local arrangements, identifying the dynamics influencing steering and changes of consumption can provide more universal contributions. The role of context is demonstrated in the study by Cherunya et al. (2020) which draws on the particular conditions in the informal settlements of Nairobi while using the empirical material in conceptual development.

The transferability issue also relates to the choice of focusing on carbon footprints and tracking related consumption data. Two potential limitations arise from this choice. First, different footprints or indicators may point to different actions to decrease the negative impacts. Second, it may be possible

that the chosen footprint or other environmental indicator has an effect on how willing people are to follow advice and take action. Regarding the first point, Simas et al. (2017) show coupling of carbon, material, water, and ecological footprints on a national level. Thus, the indicators in general would point in a similar direction. Further, it is logical that sufficiency in particular – that is decreasing the volume of consumption – would make all footprints smaller. It is more of a concern when it is suggested that a specific product, technology or raw material is suggested to be replaced with another due to its lower carbon footprint, while at same time in some cases, increasing a different footprint or impact. That is why sustainable consumption policy needs to address a range of indicators. The second point – that of people potentially being more responsive to one environmental footprint category than another – does not appear in the literature consulted for this thesis. The issue of "going beyond carbon" is addressed by, for example, West et al., (2016), who recognise that some people may be interested in other sustainability perspectives than carbon. However, evidence that one footprint indicator leads to a better response than another is, to the best of my knowledge, lacking.

Lastly, I reflect on the use of practice theory as a device in critically assessing the role of data-based applications in steering sustainable consumption policies. It can be argued that more extensive primary data, such as first-hand observations of the use of applications to track consumption and related activities, would have strengthened the study. While Articles II and V draw on first-hand observations, Articles III and IV tap into expert interviews, desktop analysis and literature review. Except for studies on energy (Hargreaves et al., 2013; Judson and Maller, 2014; Naus et al., 2014; Smale et al., 2017; Strengers, 2011), and a study on Danish footprint calculator use (Gram-Hanssen and Christensen, 2012), practice theory has rarely been applied to the analysis of steering initiatives using consumption-based data and related applications. Therefore, it is also justified to explore past experiences using other research approaches and to reframe the findings. The findings and discussion comprising this dissertation provide directions for future initiatives and interdisciplinary research focusing more closely on empirical data collection in the field of (non-)use of footprinting and metering applications.

As this dissertation aims to connect with, and contribute to, the literature on sustainable consumption policy, the question of how practice theory studies align with policy development calls for attention. Practice scholars (Shove, 2010; Spurling et al., 2013) argue that practice-based analysis could contribute to policymaking whose goal is to advance sustainable consumption. In a review article, Shittu (2019) also proposes including further practice approaches in future research on sustainable consumption and policy. At the same time, studies on practice-based research and current policymaking do not make for an easy match. Some scholars (Hampton, 2018; Shove, 2014b) underline that one challenge to integrating practice-based findings with mainstream policies

is the fact that the contributions and answers policymakers seek are set by behaviourist paradigms. Fitting the contributions into current frameworks of policymaking is especially challenging when time constrained policymakers ask for simplified recommendations, such as policy briefs (Heiskanen et al., 2014), while practice theory studies tend to reveal complexities rather than causalities (Watson et al., 2020). Nonetheless, although the integration of practice-based findings into policymaking may not be easy, this dissertation seeks to use practice thinking to indicate the challenges of data-based applications such as footprint calculators to steer consumption. Implications for the design of policies and policy mixes are presented in the Conclusions (Section 5).

4 RESULTS AND DISCUSSION

This section addresses the use of data and data-based applications to steer household consumption by synthesising the findings of the Articles I–V. The sub-sections focus on each of the three research questions, elaborate findings and further discuss them in the light of previous research literature. To present an overview, Table 2 summarises the contributions of the articles to answering the research questions.

Table 2. Summary of inputs from the articles to answering the research questions.

	RQ1. How can consumption data and carbon footprints contribute to policies of sustainable household consumption?	**RQ2. How can tailored, data-based feedback support steering initiatives?**	**RQ3. How does recognition of everyday practice dynamics reveal opportunities for, and limitations to, steering household consumption?**
I	HBS data were used to identify demographic, socio-economic and spatial drivers of consumption and carbon footprints in Finland. Results highlight the prominent role of income over other drivers.	Analysis of household consumption patterns and related carbon footprints identified areas of consumption requiring attention and steering.	The identification of drivers of consumption such as income and life phase provide starting points for identifying practices leading to consumption patterns with large carbon footprints.
II	Climate labelling and tinkering of meal and menu design were used to promote plant- and fish-based meals and increase vegetable consumption without restricting the choice of customers.	Long-term monitoring of food ingredient use and carbon footprints was used in collaboration with the restaurant to rearrange processes and types of meals served. Despite positive changes in ingredient use, changes in footprints remained small.	Experimentation and negotiations at the restaurant revealed how competing priorities require tinkering at the nexus of supply and demand to solve challenges and find ways to increase vegetable use and the share of plant-based meals served.

Table 2 continues.

	RQ1. How can consumption data and carbon footprints contribute to policies of sustainable household consumption?	RQ2. How can tailored, data-based feedback support steering initiatives?	RQ3. How does recognition of everyday practice dynamics reveal opportunities for, and limitations to, steering household consumption?
III	Carbon footprint calculators and applications alike were used as informational soft policy measures to encourage voluntary actions by ordinary people to decrease the carbon footprint of doings and consumption.	Footprint calculators and similar applications with personalised information were used as tools to engage people in the self-management of carbon footprints. However, repeated use of applications over time was often lacking.	Everyday doings were challenged by advice from the applications. Interpreting experiences with practice concepts revealed tensions and resistance from the surrounding social and material environment. Applications focus on information and their ability to rearrange the material environment and skills that shape doings is limited.
IV	The roll-out of smart energy metering is based on mandatory regulations. There are expectations that people will use the data to manage their energy use. However, the literature review found that taking up active self-management may not be realised.	Smart metering often remained disconnected from the practices it intended to steer. Still, using smart metering in novel set-ups could be a promising way forward. Metering contributes to knowledge but not necessarily to actions.	The article interpreted previous findings on smart metering initiatives from the practice perspective and reframed results from a systemic rather than an individual perspective. Change of perspective can alter conclusions and implications for policy.
V	Case studies used measures that are in line with the ideas of soft information-based and procedural policy instruments. Consumption-based data were found helpful for distinguishing major and minor impacts and directing the focus of actions.	Household and property-specific consumption and carbon footprint data revealed meaningful areas of attention. Case studies provided lessons on how information and applications are (not) embedded in the everyday life of people or working practices of intermediaries.	The case studies recognised (lack of) skills and developed tools and capabilities accordingly to address consumption and related footprints in the work of intermediaries, professional activities, and everyday lives of ordinary people.

In the remainder of this section I begin by addressing the question of the use of consumption data and derived carbon footprints interpreted as examples of sustainable consumption policies (Section 4.1). I then look more closely at the

initiatives and summarise the role of tailored data in steering them in the context of the household or everyday consumption (Section 4.2). Finally (Section 4.3), I focus on how studying practices can contribute to elaborating and understanding the potential of data and applications to steer household consumption.

4.1 CONSUMPTION-BASED DATA AND POLICY

The first research question asked: How can consumption data and carbon footprints contribute to policies of sustainable household consumption? The articles for this dissertation show how information provision, such as energy consumption, labels or footprint calculations can rely on mandatory or voluntary measures but, ultimately, the doings of people whom the data is intended to steer is voluntary, and actors may be concerned about restricting the choice too much. At the same time, the findings from a large quantitative data on consumption patterns could provide inputs for various types of policies.

The rest of this section weaves together the findings from the policy perspective, concerning the role of consumption data and applications in the case studies (Articles II, III, and V), literature review (Article IV) and econometric analysis (Article I). The section also briefly reflects on what was not found from the research material, that is, the role data potentially could have in policies of sustainable consumption. I focus on two main points: first, on the empirical findings of the type of policies to which data and applications contributed; second, I present and discuss the findings on the role played by affluence and other socio-economic and demographic drivers in high-carbon consumption patterns, and the policy implications.

STUDIED INITIATIVES AND POLICY INSTRUMENTS

The case study material (Articles II, III, and V) and the literature review (Article IV) of this dissertation focus on the role of data and data-based tools in initiatives aiming to enhance voluntary action to decrease the carbon footprint of household consumption. Following the classification of sustainable consumption policies (Wolff and Schönherr, 2011) introduced in Section 2.1, the empirical data include steering initiatives that mainly present communicative and procedural instruments (Table 3). Although smart metering of energy is based on mandatory regulations governing the installation of meters, cases reported in the literature review in Article IV focus on communicative instruments building on the data from smart metering systems. Table 3 summarises the studied initiatives by dividing measures into communicative and procedural types of instruments.

Table 3. Summary of empirical initiatives based on types of policy instruments following the classification of Wolff and Schönherr (2011).

Communicative instruments	**Procedural instruments**
Climate labelling of lunch options (Article II).	Data on the volume of food items and related carbon footprint used to support the studied restaurant's efforts to develop fish- and plant-based lunches, and nudge customers to choose more vegetables (Article II).
Carbon calculators available online for public use (Articles III and V).	
Advisory and expert activities supporting the use of consumption data, calculators, and smart metering data (Articles II–V).	
Integration of carbon emission estimations with credit card purchase data, and an online tool to compare costs and carbon emissions of car models (Article III).	Calculation tool for renovation business to guide houseowners' renovation decisions and inform them about benefits of energy efficiency improvements. Training programme to improve professionals' expertise and skills in energy efficiency (Article V).
Consumption feedback (of energy and/or water) to households via smart meter display or similar medium whose aim was to reduce overall consumption and in some cases contribute to load shifting. Data based on a literature review and a survey in Article IV.	Energy management in housing companies (typically apartment blocks) including training, follow-up of consumption data, technical adjustments and informational measures to influence the use of energy and water (Article V).
Integrating calculation tools and supporting material into the work of teachers, NGO's, energy and sustainability advisors and companies (Article V).	

While the listing in Table 3 is not exhaustive, it provides examples of a variety of measures to inform and persuade ordinary people to take action to change consumption patterns. Data and applications were used in households' self-management activities (calculators, smart metering), practice-specific processes (lunch serving, home renovation planning) and initiatives to track and tackle energy consumption patterns in apartment blocks with technical and communicational measures. The applications or data were often combined with other means of support such as communication, personal or group advice from a sustainability professional, adjusting technical systems and informing decision-making.

Drawing the line between communicative and procedural instruments is a matter of definition. Here, I have used the following principle as a guide: if data and information are used to work towards a specific goal to which the actor has already committed, then I have classified it as a procedural instrument. Some of the informational instruments also aim at making rearrangements, but differ from procedural instruments in that their role is more informative and leaves open the realisation of activities. In other words, I interpret informative measures as those aiming to persuade people to take action without restricting their choice, while procedural measures direct the

activities of already committed actors, altering consumption patterns 'behind the scenes'. Some measures classified as informational measures have characteristics of procedural instruments, such as when data and data-based tools are integrated into the professional practices of primary education; however, in these processes I still regard the role of data and tools as being more informative, rather than contributing to a specific, goal-oriented process. I argue that using the two categories can illustrate the role and connections assigned to consumption data and applications. Making this distinction is more important in the context of this dissertation than distinguishing the borderline cases.

In the case of lunch service (Article II), for instance, or energy and water systems in apartment blocks (Article V), procedural instruments reduce the need for people to make a conscious effort to change doings, at least in some ways. Other cases in Articles III–V mainly focused on rationalising consumption and guiding purchase patterns and doings; in other words, applications and in some cases personal consultation relied on passing on information and recommending activities based on reported consumption, energy use or footprint. The initiatives listed in Table 3 focus mostly on decision-making that prioritises environmental sustainability; however, many initiatives also build on the rationale of saving money by improving energy efficiency and cutting energy or water waste.

Overall, the consumption-based data were seen as valuable in initiatives in making a difference between small and large impact actions (Articles II, III, and V), thereby guiding the focus. The guidance of direction has considerable worth as actions are not equal in terms of their potential impact and significance; however, guidance does not guarantee that actions will deliver major changes, as I further elaborate in Section 4.2.

Using the applications and participating in initiatives was voluntary in all the case studies. Therefore, it was a prerequisite that actors found the idea of changing patterns of consumption meaningful or at least acceptable for environmental or related economic reasons. On the other hand, relying on voluntary participation leaves open the question of whether soft measures will deliver changes at the scale required.

To summarise, the studied initiatives mostly represent forms of soft, informational and procedural instruments. In terms of efficient policy mixes, it is essential to look beyond the listed measures. Optimally, communicative instruments would be pieces in the policy mix puzzles, supporting other measures; their relation to hard measures such as regulations and economic incentives is especially important. Reflecting on the experiences and challenges of the case studies, this was not always the case, as Section 4.2 highlights.

THE ROLES OF AFFLUENCE AND ACCESS AS DRIVERS OF CARBON FOOTPRINTS

Article I studied drivers of household consumption expenditure and related carbon footprints in Finland. The descriptive analysis showed that variation in footprints among households is wide. Nevertheless, the mean value of carbon footprint per household, with an average 1.77 inhabitants, was 19 tonnes (Article I). Hence, the average footprint is large compared to the level compliant with the estimated 1.5 degrees path: 2.5 tonnes per capita in 2030 (Institute for Global Environmental Strategies, Aalto University, and D-mat ltd., 2019) and even lower in the following decades (Fauré et al., 2016; Rockström et al., 2017).

Income was identified as the strongest driver of household consumption and footprints (Article I), result which resonates with previous research on the phenomenon (e.g., Nässén, 2014; Wiedenhofer et al., 2018; Zhang et al., 2015). My interpretation is that higher income increases consumption opportunities, both low-carbon and carbon intense, and ways to conduct everyday activities. In other words, access to affordable, carbon-intensive means and technologies for arranging everyday life increase along with income.

Article I used an extensive set of explanatory variables on the demographic, socio-economic and spatial characteristics of the households; however, environmental attitudes were not included. It is reasonable to ask if pro-environmental attitudes explain some of the differences in footprints but, so far, results from other studies do not look very promising. Moser and Kleinhückelkotten (2018) argue that even pro-environmental mindsets are overridden by the increase of consumption opportunities that come with higher income. Good intentions and inflated perceptions of environmentally friendly actions may overestimate actual doings, especially those related to major sources of impact (Whitmarsh, 2009). Therefore, analysis covering all areas of household consumption is required to track overall development in terms of following policies and actions. The notion applies to every level, from a single person to a household, and all the way to the national level.

Research using psychological and behavioural approaches (e.g., Poças Ribeiro et al., 2019) has concluded that consumption responds to the biological and emotional needs of social human beings. Currently, the everyday environments in affluent societies provide unforeseen opportunities – or affordances as Kaaronen (2017) terms them – to satisfy these needs, starting from what is nowadays seen as basic infrastructure in affluent societies, such as piped water, electricity and road networks. Further, tangible items, such as motorised vehicles, household goods, electronic gadgets or the variety of food items available, illustrates that the means to satisfy perceived needs and conduct everyday practices are unprecedently extensive for those who can afford them. The empirical data raises questions about expectations of how shifts in consumption patterns will further a circular economy or realise

the modelled potential to curb the GHG emissions of household consumption (see Section 2.1).

In high-income countries the problem is not only the consumption of the wealthy few. As Lettenmeier et al. (2014) show by using the material footprint indicator, even households from the lowest income decile in Finland had patterns with larger material footprints than long term sustainability targets would require. Moreover, the ranges and averages of Finnish households' carbon footprints (Article I) and those by income deciles reported by Salo et al. (2019b) support the argument. In other words, carbon-intense forms of practices are built into the normal ways of conducting everyday activities. Hence, I remain cautious about the power of information, as such, to steer consumption at the scale required if prevailing social and material circumstances lack support for such change.

However, as Kokoni and Skea (2014) point out, carbon footprint data can be applied to various policies, not only informational measures. Consumption-based data could also feed into the development of regulations, pricing and taxation. Importantly, infrastructure provision is also a policy measure (Wolff and Schönherr, 2011). Data could also be used to set consumption-based targets and used to facilitate processes of identifying problems and finding solutions when moving towards those targets (Institute for Global Environmental Strategies, Aalto University, and D-mat ltd., 2019), in order to address issues such outsourcing production-based emissions, for example, away from cities (Ottelin et al., 2019), as well as evaluating impacts of policies already in place, as in a Swedish study by Schmidt et al. (2019).

Research and large-scale, consumption-based data are important to indicate, for instance, carbon intensive areas of consumption or how life situation (age, occupational status, number of persons in a household and spatial factors, as identified in Article I) drives carbon footprints. Yet, while identifying spatial characteristics supporting low-carbon living can inform land-use and planning policies, interpreting demographic and socio-economic drivers is less straightforward. If certain patterns of consumption and doings are interpreted as arising from the life-phase, time pressures and social environment affecting norms, for instance, policy mixes could be developed to target these collective patterns of doings. Hence, the role of consumption data would be to serve as input for policy development.

4.2 DATA-BASED FEEDBACK SUPPORTING STEERING INITIATIVES

The second research question to guide this dissertation was: How can tailored, data-based feedback support steering initiatives? In brief, the articles reveal how data indicate relevant areas of attention in various contexts: populations, communities, households and practices. The findings suggest that, even where openness to receiving information and thus gaining new knowledge is present,

it is not easy to embed a self-managerial approach in terms of monitoring consumption data and changing consumption accordingly. Nevertheless, the role of data can extend beyond individual self-management and be used to support collective changes.

The remainder of this section presents the role of data in steering initiatives in more detail and discusses the related findings. In general, quantitative data are valuable to direct focus. Large datasets (e.g., HBS as in Article I) have shown that the areas and volume of consumption require changes and steering to decrease carbon footprints. The initiatives studied in this dissertation tackle one or several key areas of consumption: food (Article II); car choice and driving (Article III); energy use at home (Articles IV and V); and the combined footprint of several areas of consumption (Articles III and V).

In the subsections below, I first summarise empirical findings on how people engaged with the data, applications and advice. I reflect on the results in the light of concepts on the acceptance and embedding (see Sections 2.1 and 2.2) of new items or services in everyday life, and discuss the relevance of findings for future research and development of data-based applications and initiatives. Second, I reflect on empirical findings on the volume of changes in consumption and carbon footprints. Third, I elaborate on the potential of collaborative processes and the role of intermediaries using consumption data as input to reshape doings.

The case studies mainly comprise initiatives steering consumption within the existing material and social environment; however, some of the studies also examine activities designed to tune the supply, adjust the material setting and develop skills and competencies. Initiatives to steer household consumption include activities in which data and applications are tools for self-reflection and management (Articles III–V), platforms for campaigns (Article III) or tools for intermediaries to use (Articles II–V).

EMBEDDING APPLICATIONS AND GUIDANCE IN EVERYDAY DOINGS

Information, feedback and suggestions for action that are based on measured or self-reported consumption patterns provide meaningful grounds for rational reflection and decision-making (Articles II–V). Many studied applications have features servicing the aim of encouraging users to follow changes in their consumption over time in order to reflect on impacts resulting from actions taken (Articles II–V). Thus, the features found in the studied applications suggest that they are designed for repeated use and reflection on consumption in the long term.

However, results suggest that engaging people in repeated interaction with calculators and metering systems over time is a goal that is not always realised (Articles III and IV). Therefore, the outcomes resonate with, for instance, the findings of Hargreaves et al. (2013) on smart metering systems and of Collins et al. (2020) on ecological footprint calculator use. The lack of repeated use is

problematic given the expected self-reflection and self-management approach to using applications and data, as discussed in the literature (Article IV), and in analyses of footprint calculators and related initiatives (Articles III and V). In other words, a lack of long-term engagement is problematic if the expected mechanism of change relies on repeated reflection of doings with the help of the application.

Technical deficiencies and insufficient or cumbersome application characteristics can also play a role in the lack of engagement, and West et al. (2016), for instance, argue that in terms of design and coverage there is much to be improved. While technical issues were recognised in Articles III–V, the findings (including Article II) also indicate that resistance to engaging with the application or acting according to the advice can be due to conflicting priorities, such as comfortable home conditions, the dietary preferences of other people or time use patterns. While developing technical features enabling the collecting, processing and communicating of data are likely to improve many aspects of the applications and feedback in the future, there may be issues that technically more advanced tools are unlikely to solve. These relate to the inconsistencies of feedback and suggestions in relation to existing practices and everyday life.

To elaborate further on the limitations of relying solely on improvements in the applications to effect future change, I draw on differences between the characteristics of acceptance and embedding (Camacho-Otero et al., 2018; Cherunya et al., 2020) introduced in Section 2.1: two concepts that are useful when reflecting on the low level of engagement with the applications and feedback (Articles III–V). More specifically, even if people are concerned about their carbon footprint and other environmental implications of their consumption and, therefore, are interested in knowing and doing something about it, they may be reluctant to use tools provided for information and guidance. Acceptance, in this case, is related to alignment with the idea – or meanings, in practice theory terms – that one's consumption is problematic from the environmental perspective and requires changes. In real life, potential users of applications are those who share the concern for environmental sustainability.

While acceptance is a prerequisite for engagement, it does not guarantee that the application or advice provided will be embedded in people's everyday doings to guide changes. Other priorities in life can hinder the embedding or adoption of data and applications; for instance, family-related priorities may be perceived to conflict with energy or carbon rationalities. A study by Moser and Kleinhückelkotten (2018), resonates with this argument, noting that intention-oriented and impact-related research approaches deliver differing results on the environmental burden of people. Whereas acceptance relies on the alignment of meanings, embedding requires the alignment of material dimensions and skills; embedding applications and activities that rearrange practices also requires negotiation between conflicting meanings. Figure 2

below aims to illustrate, on a conceptual level, the alignment of practice elements in terms of acceptance and embedding.

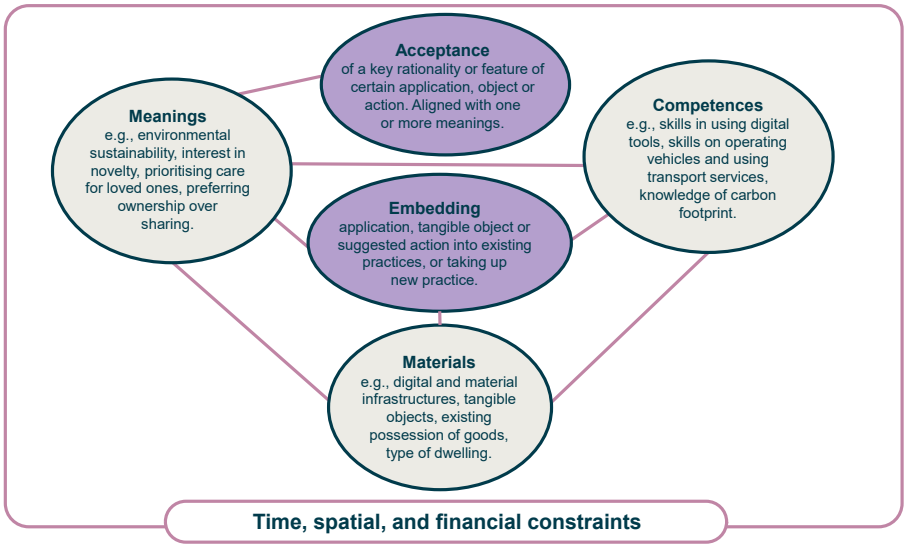

Figure 2. Illustrating the alignment of acceptance and embedding using practice elements. The figure draws on the conceptualisation of practice elements (Shove et al., 2012) and the concepts of acceptance and embedding (Cherunya et al., 2020).

Figure 2 also recognises the constraints of time, space and finance in order to highlight how everyday life dynamics play a role even if all the elements exist in principle. Their adoption might require more time, for instance, and therefore rearrangement of several practices instead of a single one. The importance of the time (space) dimension and the sequential nature of practices are recognised in the literature of everyday practices (Gram-Hanssen et al., 2020; Shove et al., 2009), illustrated, for instance, in an empirical study on shared electric vehicle use (Sopjani et al., 2020). Spatial constraints, which are often tightly connected to the time dimension, play a role if engagement with certain practices would require the rearrangement of activities in terms of location and distance. In addition, financial costs can be a limiting factor, while renegotiating the allocation of expenditure may also be an issue. Therefore, lower prices may not always guarantee a change of practices due to conflicting priorities or for time-related reasons. The outcome is that the embedding of applications and their tailored advice into everyday life may require negotiation over, and rearrangements of, time and financial resources.

To summarise, I return the focus to empirical findings concerning the challenges to repeated use and following advice. The notion that tailored data, metering and advice may conflict with social and material elements resonates with results from a long term experiment on smart energy metering (Hargreaves et al., 2013), which underlines the lack of policy and market

support for change. West et al. (2016) emphasise that the role of informational measures such as footprint calculators is to complement a supporting environment and infrastructure. Nevertheless, the role of external factors in shaping consumption is absent in some studies focusing on the type and quality of information on energy feedback (e.g., Gabrielli et al., 2014; Karjalainen, 2011).

The discussion above suggests that even improved information may remain detached from activities it is supposed to change. I argue that attending to the complexities of renegotiating connected practices should not be ignored in studies and development of data-based tools and related policies, simply because it is messy, difficult to tackle and hard to control. Instead, future research should try to find ways to identify connections that support solving the practical puzzles of rearranging doings. I do not question the need to improve metering and access to information. My point is that the developers and the policymakers putting together policy mixes, should recognise that feedback and action do not only depend on the interaction of application and users but are greatly influenced by the societal context.

TAKING ACTION BUT DELIVERING MINOR ADJUSTMENTS

My next focus is on the volume of changes delivered. First, it should be clarified that while Article II collected and analysed long-term quantitative data, other cases in the thesis use some quantitative figures but mainly rely on qualitative material based on expert interviews. Therefore, I reflect on quantitative findings versus qualitative insights rather than providing a quantitative summary of the volume of changes.

Tailored data and advice based on measured or self-reported patterns of consumption are relevant to putting actions into the same perspective as the total consumption and footprint. Showing the contribution of potential or executed actions informs people about the order of magnitude of different actions. Nevertheless, despite considerable effort and pro-active behaviour, the impact in terms of volume of consumption or emissions may be rather small (Articles II–IV). The tendency to engage more with lower than higher impact actions is reported in many previous studies (e.g., Whitmarsh et al., 2011). It should be pointed out, however, that restaurant personnel interviewed for Article II were satisfied with the small changes in food choices made by customers in the pursued direction, articulating that radical changes would be unlikely and even worrying from their perspective. Observations about the rather small footprint impact of reported actions have also been made in previous studies (Bruderer Enzler and Diekmann, 2019; Moser and Kleinhückelkotten, 2018): reported pro-environmental activity correlates weakly with the total footprint. One possible explanation is that the effort, cost and inconvenience of taking minor or major impact actions are very different from one another. For instance, recycling is a rather easy way to take action if decent facilities are in place and it takes only a little effort or sacrifice

(Whitmarsh, 2009). Moreover, many major impact actions are perceived to be non-negotiable as they would not comply with current standards of comfort and convenience. Yet even adjustments which only deliver small changes can be perceived as requiring effort, time and resources.

For Article II, quantitative data on food item use in the case-study restaurant were gathered over four consecutive years. The data were also used to estimate carbon footprints as a proportion of the number of meals purchased. The figures provide a rough but informative[5] indicator of the type of food served and changes in its content and carbon footprint per meal over the years. However, attempts to quantitatively follow up several areas of consumption on a household level is more complicated, as flows of energy, money, goods and so on are multiple and there is no predefined system or purpose for collecting all the data for footprint-tracking purposes. The challenge is reflected in Articles III and V, which indicate that developing tools to use consumer input and in some cases combine it with automated data collection is a resource-intensive task. Further, systematically controlling input to monitor consumption in order to draw robust conclusions on changes would require more planning and resources. Ultimately, the case studies focused on developing and experimenting with tools and applications instead of systematically studying their impact.

The data collection process of household consumption expenditure by Statistics Finland (Statistics Finland, 2018) is one illustration of a laborious exercise in mapping how much households spend and where it is used. While the carbon footprint calculations in the studied initiatives (Articles III and V) did not require such a high level of detail, self-reporting can be an effort. For example, the level of detail in calculators which address multiple areas of consumption is quite superficial; meanwhile, calculating ones' footprint multiple times may provide different results not only due to real changes in doings but also based on the accuracy of the input data. This presents the question of whether it is possible to distinguish the precise part played by actions taken as a result of the initiatives from other changes in everyday life circumstances. Increasing the share of automatic data collection eases the burden of manual input; however, while this decreases the inaccuracies of manual input, credit card purchase or energy consumption patterns, for instance, may vary for a number of reasons, in addition to actions taken to decrease or shift consumption due to environmental concerns.

One interpretation of this situation could be that these challenges are technical problems to be addressed by the developing accuracy of tracking systems (see Andersson, 2020 for a description of one application), and combining the figures with other data input explaining changes in patterns.

[5] Data collection and carbon footprint estimations were not without challenges. However, the consumption data covering all items coming in and reliable data on the number of meals sold provide fairly accurate figures which could be used to follow changes in types of ingredients used and related carbon footprints.

Another interpretation, drawing on practice thinking, is to understand the challenges as an illustration of the complexity of everyday life and embedded consumption in relation to the social and material circumstances.

DATA AND APPLICATIONS CONTRIBUTING TO THE WORK OF INTERMEDIARIES AND COLLABORATIVE PROCESSES

Digital tools can be seen as a cost-efficient means to reach a large audience and provide people with tailored guidance without resource-intensive personal consultations; still, many initiatives included interaction with experts or peers (Articles II–V). The role of experts was found to be valuable in guiding participants, showing greater sensitivity to their life situations and the kinds of actions to suggest compared to suggestions by the metering and footprinting applications (Article V). Summaries and calculations based on data, and even tailored advice, may be difficult to understand, confusing or cause defensive reactions due to the (perceived) necessity to conduct everyday activities in certain ways.

While expert intermediaries can serve as interpreters of information (Articles II–V), improved knowledge may not translate into action (Article IV). Initiatives providing more concrete support in rearranging the material or social elements and supporting skills development may offer a potential way forward. My interpretation, drawing on practice thinking, is that intermediaries may facilitate the making and breaking of links with practice elements (Shove et al., 2012) to rearrange doings.

Intermediaries are potential adopters of the applications to support their professional activities in sustainability communication or advisory work (Article V: teachers, municipal energy advisors, renovation business, NGOs). However, introducing the applications to intermediaries is hardly enough, as it is time- and resource-consuming to embed tools into working practices and processes. Rather, co-development with those using the tools enhances the fit and usability of a tool for the specified purpose (Article V). Hence, differentiating between acceptance and embedding (see Sections 2.1 and 2.2) is also relevant in adjusting professional practices. Recognising the difference relates to the role of intermediaries: Are intermediaries seen as a means to distribute the application to their networks or as actively adopting them in their work?

In regard to experiments and initiatives, the integration of data into facilitated processes provides some promising avenues, as illustrated in Articles II and V. The cases in Article V demonstrate that consumption data can provide information on the energy management of apartment blocks and small renovation businesses focusing on detached houses, which can impact on activities rather than merely informing. Data can guide the transformation of the material setting, prompting technical adjustments of existing systems and thereby affecting energy use and the carbon-intensity of energy sources used.

Article II focuses on practices connected with preparing, serving and eating lunch at a workplace restaurant. Quantitative data on food item use and the carbon footprints of the food served were mainly used in the collaboration process with restaurant personnel to support their activities in tuning supply. Hence, the quantitative data were not used to steer customers directly when they visited the restaurant but rather worked in the background to steer supply.[6] Thus, the case exemplifies the interconnected practices of consumption and production. Both restaurant personnel and the corporation were committed to developing supply and making adjustments. Despite the commitment, the restaurant had to ensure it would not lose business due to changes which were too radical, as its customers had other lunch options. Therefore, the steering attempt was also influenced by what was available 'outside of the studied system', that is, in other (nearby) restaurants and the homes of the customers in the case study.

To summarise, data and applications used as procedural instruments in collaborative processes provide a promising way forward. However, it seems likely that the resources and mandate to rearrange elements of practice according to data guidance are essential. Therefore, data are one, but not the only, element contributing to driving change. Moreover, if policy instruments to steer practices towards environmental sustainability in society at large are lacking, ambitious reorganisation in single households and companies, for instance, may be difficult due to conflicts with prevalent norms and practices. In other words, anticipated outcomes exceed the resources and mandate of participating actors (Berg, 2011; Watson et al., 2020).

4.3 RECOGNISING THE COMPLEXITIES OF EVERYDAY PRACTICES

The third research question was phrased as follows: How does recognition of everyday practice dynamics reveal opportunities for, and limitations to, steering household consumption? Drawing and reflecting on the data used in this dissertation, the practice perspective reveals negotiations, tensions and resistance when current practices and consumption patterns are challenged. Recognising the complexities of practices and the role of the surrounding material environment, shared meanings – including ideas on normal and desirable everyday life, and competencies to conduct activities – unfolds the interplay of data-based steering with the surrounding society.

The two sections below discuss further the value of practice thinking to interdisciplinary research on steering practice in the direction of sustainability with data and applications. First, I address how using a practice approach to

[6] Summaries of the carbon footprint were presented annually to the customers –those working in the office – as part of the institution's sustainability reporting. Climate-friendly lunch options were labelled on the menu, without presenting the carbon footprint in numbers.

explore relations between applications and social and material context assists in identifying underlying reasons for the opportunities, and especially the challenges, facing applications designed to steer consumption. I aim to show how practice theory can provide a potential framework for researchers, developers and policymakers working on data-based applications. Second, I draw on the practice literature and position my findings on the basis of the critique that practice scholars have presented of data-based steering measures.

PRACTICE THINKING AS A SENSITISING DEVICE

Statistical analysis of extensive data (e.g., Article I) identifies areas of consumption with significant carbon footprints, as well as their drivers. For instance, age group and other demographic and socio-economic drivers provide hints about life situations which are related to gradations in carbon footprint size. However, the drivers, as such, do not provide detailed information about practice arrangements leading to large footprints. In Article I, the authors suggested that a practice perspective may be one way to unpack the problematic practices leading to large footprints and identify the means to steer them.

Practice theory highlights that the obduracies and change trajectories of everyday doings are rooted in the arrangements of practice elements, for instance, the development of car dependency (Shove et al., 2015). Practices build on infrastructures and other material elements, and other practices then become dependent on them, as in the case of prevalent mobility practices. As discussed in Section 4.1, the studied applications rely mostly on environmental aspects' being prioritised through rational reflection, yet, as Section 4.2 elaborated, acceptance of the idea of striving for environmental sustainability may not be enough to embed solutions that would rearrange one's daily activities.

Recognising how doings take shape and change is relevant when considering the role and realistic expectations of soft policy measures' relying on information and data to steer consumption. Figure 3 illustrates two perceptions of how data, feedback and advice can be seen as reshaping actions. On the left, sources of acceptance and resistance are rooted in the mindset and knowledge of an individual; meanwhile, the figure on the right illustrates how embedding, compliance, and resistance are rooted not only in the individual mindset but, more prominently, in the surrounding material and social environment. Further, underlying energy, transport and data infrastructure is essential in servicing practices and shaping the use of tangible objects. Figure 4 draws on the findings in Articles II–V on what hinders the adjustment of doings and consumption according to data-based feedback. Tensions arise

from issues such as money, time, preferences (of other people), perceived necessities and perceptions of a comfortable life.

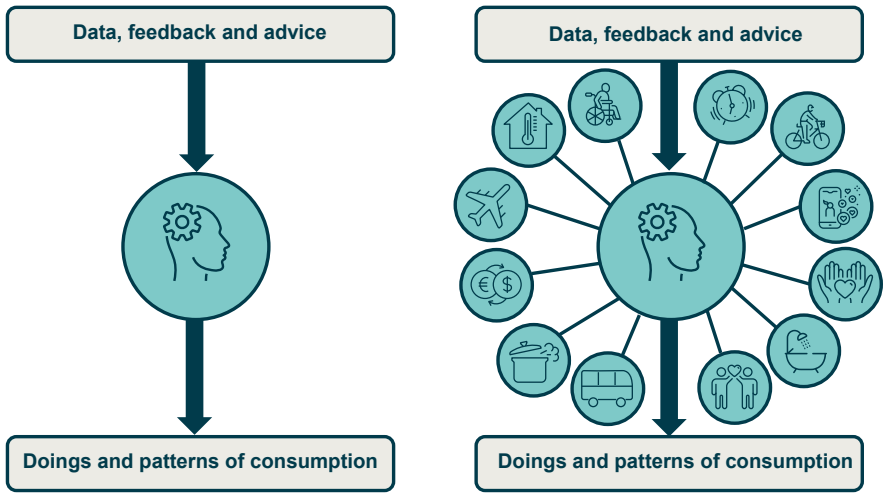

Figure 3. Two perspectives on how information is perceived to steer doings.

A reluctance to change practices in the direction of environmental sustainability may lead to the illusion of the stability of current practices. However, over time one can track the introduction of new luxuries that have slowly been adopted more widely to become the new normal, for the majority at least. Examples include the increase of meat in affluent diets, the transport modal share of passenger cars and air-conditioning systems that maintain indoor temperatures at 21°C around the year. When certain practices and technologies become accepted as part of normal life, it may be difficult for individuals to opt out of default types of practice. Think, for instance, of the use of mobile phones or passenger cars in a society where the majority of the population own and use these devices and vehicles.

Drawing on the discussion above, I argue that applying practice thinking to studying and developing data-based steering is helpful in analysing the underlying reasons for (the lack of) engagement with the applications (III, IV) and resistance to taking the suggested action to decrease consumption (Articles II–IV). Concerning the underlying reasons, I refer to how Articles II–V illustrate relations between applications and material and social contexts, as well as personal knowledge and skills, and how these observations can be used to analyse the opportunities and challenges to engaging people in using applications and following the given advice. Hence, (re)framing findings from a practice perspective provides a systemic view of the problem rather than merely focusing on finding the means to convince and motivate individuals.

Previous research has called for more emphasis on the embedding and adoption of innovations and new services (Camacho-Otero et al., 2018; Cherunya et al., 2020). I argue, in line with Cherunya and colleagues, that

practice elements provide a promising analytical framework for revealing insights on embedding, as they help to map what people do and say. While actions and emission accounts are what matter in the end, the things people say are essential as well as they can reveal the reasons and rationalities behind not embedding certain items, services or ways of doing in the everyday.

Qualitative observations drawing on practice thinking, combined with quantitative numerical analysis of changes in patterns of consumption, provide a research approach that pinpoints and analyses connections and disconnections with everyday life. This combination is especially relevant when the goal is to develop effective steering measures and policy mixes that may benefit from data-based applications. To unleash the potential of quantitative data and applications, the emphasis on improvements in the quantitative measures must extend beyond improving the design of a single application or metering. The role of quantitative measures is also an issue, as it is important to distinguish the difference between identifying areas of action and the means to facilitate change.

REFLECTING ON PRACTICE-BASED CRITIQUES OF DATA-BASED STEERING

A number of practice scholars have critiqued data optimism, smart solutions and notions of assigning responsibility, criticising carbon footprint calculators for emphasising individual responsibility, as noted in Sections 1 and 2. In this light, the rather moderate engagement with applications and changes in doings reported in the case studies of this dissertation are not surprising. I agree with the argument that using calculators or applications as a means to highlight individual responsibility is problematic, arguing further that the role of data and data-based applications should extend beyond the individual perspective. Applications, as such, can contribute very little to changes in material settings (Articles III and IV); on the other hand, they potentially have a role in showing and making connections between existing and novel elements.

Consumption data, tracking and footprint calculations can be incorporated as elements in collaborative processes (Section 4.2) in which the tools could be used to direct collective solutions and actions. In practice terms, this implies that material elements would be rearranged, skills developed and shared meanings renegotiated. Data and applications would not be seen as solutions as such, but rather as tools and materials to guide the transformation. The processes likely require the intensive participation and collaboration of actors from various sectors instead of expecting people to manage significant changes independently at a household level.

Scholars have also critically commented on the potential of the roll-out of smart energy metering (Hargreaves et al., 2013) and smart technologies (Strengers, 2013) to decrease energy consumption. Empirical studies that focus on applications building on the smart metering infrastructure indicate

that they often lack users' active and long-term engagement (Article IV). Furthermore, smart metering initiatives have revealed (perceptions of) non-negotiable conditions, items and doings that people are not willing to compromise for energy savings. The empirical data in this dissertation have provided the tentative results that carbon footprint applications in their current forms can face similar challenges (Articles III and V). Therefore, the role of data and applications in contributing to steering household consumption carbon footprints needs to be critically considered to avoid overly positive expectations of their power to reorganise the doings of a large number of people. In addition, the potential should be considered as a measure in a policy mix.

The promise of smart technologies to improve energy efficiency and therefore have a positive environmental contribution has been criticised for dismissing the rising standards of living, comfort and convenience that offset the improvements of efficiency. Using consumption data to steer and direct the focus of action, in principle, provides opportunities to advance sustainable consumption and doings from different perspectives. However, as Articles III and IV in this dissertation illustrate, challenging prevalent standards of comfort and convenience on a household and practice level is likely to meet with resistance. Rather than neglecting these approaches, they deserve more attention and a rethinking of the role of data and applications and, most importantly, exploration of other elements to tackle the problem: in other words, additional ways to steer beyond raising consumer awareness or increasing efficiency should be sought.

As data and applications can be used to encourage a shift to more efficient technology or use patterns (i.e., avoiding wasteful use), they could also highlight the impact of sufficiency approaches focusing on the total volume and type of consumption. Therefore, it is up to the designers, policymakers and intermediaries to remain conscious of the chosen approach(es) of the data-based measures and recognise the underlying aims and possible positive or negative side-effects. As the literature review in Section 2.1 suggests, it is also beneficial to recognise that efficiency and sufficiency are not separate from each other but, rather, connected. How consumption data and applications could be used to reveal this connection and contribute to coupling of efficiency and sufficiency remains a topic for further research. I use the concept of coupling here to underline the need to improve efficiency while at the same time curbing the demand for a resource, product or service.

Growing affluence and rising incomes (Article I), discussed in Section 4.1, tend to elevate the standard of living, which is likely to lead to more pressure on the environment. The role of income not only shapes daily life in individual households but also collective perceptions of normal ways to conduct everyday activities. In this vein, I find money is analogous to how the role of energy has been addressed in the practice theory literature (Shove and Walker, 2014). Money and energy are not important, per se, but they alter the means for conducting meaningful activities or accessing certain activities in the first

place. The abundance of affordable energy and middle-class incomes have shaped both material environments and collective ideas of a decent and comfortable life. If consumption data are to make a more ambitious contribution to environmental sustainability, they need to be harnessed to reshape standards on a collective level. Here, the role of data could be developed to illustrate tailored possible pathways to reaching a sustainable footprint level; importantly, the illustrations and processes should not be limited to individual households as the gap between one's own and the sustainable footprint may be so vast that reaching it via with the suggested actions might be overwhelming (Article III).

The case studies in this dissertation reflect the context of everyday life of affluent populations in the 2010s, given that consumption and everyday arrangements are context-specific. In addition, the role and meaning of the now voluntary-to-use applications would drastically change if, for instance, compulsory personal carbon quotas were introduced. I refrain from taking a position for or against such a measure, with its features of a regulatory and economic policy instrument. I mention quotas to illustrate two points. First, leaving practical implementation issues aside, a quota is an example of a hard policy instrument relying on consumption-based data. Second, implementation would likely make us all interested in following and planning our life with the help of a tool that keeps track of our usage and the availability and maybe trading of the carbon quota. Therefore, the role of the application, as an element of practice, would be redefined. Accessing carbon data would become as important as taking care of our personal and household budgets in units of money.

Nevertheless, closing this section by over-emphasising soft vs. hard policy measures, and focusing on underlining the role of the individual as the key decision-maker responsible for solving the problems of consumption would be a mistake. Hence, I underline the future need to study and seek approaches to using consumption data to steer and redesign the environments and elements shaping consumption and doings collectively.

5 CONCLUSIONS

This dissertation has studied consumption data and data-based applications as a means to steer household consumption. The findings show that data-based applications, such as carbon footprint calculators and smart metering, used as soft informational policy instruments are often challenged by the lack of embedment and integration in everyday activities; there is also resistance to following the suggested advice to change consumption and doings. Understanding the development and change trajectories of practices as the underlying reason for consumption is relevant to understanding the potential of, and challenges to, applications. Based on the findings, I argue that approaching data, applications and feedback as elements to be embedded in and to confront existing everyday practices can reveal their challenges and unleash their potential.

In this concluding section, I summarise the findings and discuss the empirical, methodological and theoretical contributions of the dissertation (Section 5.1). Then, in Section 5.2, I list recommendations for practitioners and policymakers on steering household consumption with data and data-based applications. Section 5.3 outlines ideas for further research and Section 5.4 provides the closing remarks of the thesis.

5.1 SUMMARY OF THE FINDINGS AND CONTRIBUTIONS

To summarise the answers to the dissertation's research questions, I begin by elaborating on how consumption data and carbon footprints contribute to policies of sustainable consumption and production. The empirical data on steering initiatives focused on voluntary informative and procedural measures. The initiatives and people involved were either not in a position to restrict people's choices (e.g., those of their customers), or refrained from doing so. Rather, data were used in direct communication with users or to facilitate the work of professionals and intermediaries to support low-carbon choices and consumption patterns. At the same time, the econometric analysis of Finnish household consumption expenditure data showed that household footprints tend to grow with income and are also affected by other socio-economic, demographic and spatial drivers. I return to the connections between affluence, consumption opportunities and voluntary informational policy measures below.

Directing the focus towards the more practical use of tailored data and data-based feedback in steering initiatives shows that data can be used to guide attention to consumption and activities, with a major impact on consumption and footprints. Using the tools can also contribute to knowledge,

directly or with the support of intermediaries, but knowledge and interest do not always translate into long-term engagement with data-based applications or actions contributing to a significant decrease in consumption or footprint. The data suggest that, while technologies of data collection, integration and consumption data presentation can be improved, the deficiencies are not the sole reasons for the lack of action or ambition to make change. Tensions and conflicts arising from current, normalised, everyday doings and negotiating priorities may hinder take-up. The finding has implications for consideration of the potential of data-based tools and their role in policy to steer consumption.

Recognising everyday practice dynamics can reveal the opportunities and limitations of data and data-based tools to steer household consumption. I argue that practice thinking can capture and depict challenges rooted in, and arising from, the material and social settings in which people live. While data-based tools can suggest and guide people and activities, concrete support remains mostly outside the scope of the tools. As underlined above, these observations should have implications for sustainable consumption policy design and the roles that applications are assigned. For instance, instead of seeing data and related applications mainly as self-management tools, the identified key areas of intervention should be addressed in policies affecting collective patterns of housing, transport, eating and other forms of consumption.

Before discussing the scientific contributions of the dissertation, I first highlight the empirical perspectives. The econometric analysis (Article I) supports the existing body of research on the prominent role of income as a driver of household carbon footprints. I interpret the finding to mean that a rise in income increases access to all kinds of goods and services. Although affluence allows low-carbon choices despite their price, income increases the opportunities to grow the total volume of high-carbon consumption. When the average per capita carbon footprint in a population is far above global sustainable averages, this means that carbon-intense patterns of consumption have become the normal way of living despite their negative consequences.

The reported challenges to initiating long-term, repeated use of data-based tools and pushing for changes in doings in steering initiatives should be taken seriously in future practical initiatives and policies relying on data-based applications. While the number of studied cases was limited and focused mainly on the Nordic countries, the review in Article IV suggested that similar challenges have been reported in smart metering studies before. Thus, although the findings and conclusions are based on limited and mostly qualitative data (discussion on limitations in Section 3.3), they provide novel input to inform the design of future research on data-based steering applications, initiatives and policy.

The methodological contribution of the dissertation is to show that practice theory offers a useful approach for interdisciplinary studies on data and applications to steer consumption. The value of the practice approach is to

show how resistance arises from current practices and norms, and the material and social environment. This makes it possible to distinguish the hindering factors of an application's characteristics from those that arise from the routinised doings of people and surrounding society.

The theoretical contributions of the dissertation arise from aligning the findings with previous practice-based critiques on carbon footprint calculators and smart metering. I agree with the recommended caution with regard to the power of data and applications to steer consumption if their role is mainly informative, and if initiatives lack the resources and measures to rearrange the material and social elements of practices. However, as practice thinking can reveal tensions arising from expected changes in everyday doings, the perspective would be of value in highlighting how the changes could be supported by the material and social environment, and new skills.

I argue that rethinking the role of consumption-based data and related applications from the practice perspective could direct focus and unveil novel mechanisms of steering with an emphasis on collective doings and consumption patterns. In addition to directly informing and persuading individuals, households and communities, consumption-based data could inform policymaking and contribute to various soft and hard policy measures in order to steer consumption. From an everyday life perspective, for instance, economic and regulatory measures based on data would also change the role played by data and applications as elements of everyday practice. I see that critique of applications from the practice perspective is justified, yet reconsideration of the role of data and applications as part of the policy mixes may present new opportunities.

5.2 RECOMMENDATIONS FOR POLICYMAKERS AND PRACTITIONERS

The steering of consumption and everyday doings in order to respond to environmental problems is necessary. Actors from for-profit organisations, NGOs and public organisations, as well as policymakers from local to global institutions are potential actors in calling for and developing data-based policies and initiatives to steer household consumption. Drawing on the findings of this dissertation, I summarise recommendations for actors working in this field.

1. Utilise consumption-based data to identify areas of intervention and policies that focus on high impact practices and consumption. Map the current problem, how it has developed over time and the key elements that are enabling current practice and consumption. Consider the role and potential uses of data to contribute to policies and steering measures.

2. Consider how applications and data-based measures relate to other steering measures and the prevalent systems guiding the doings you aim to change. Pay special attention to the expectations attached to informational instruments in areas where other, especially hard, policy instruments may have counter effects. In other words, consider if it is justified to expect informational measures to deliver major shifts in consumption and doings if the current unsustainable forms are supported by prevalent social and material environments, and relative costs of goods and services.
3. When monitoring and studying an ongoing data-based initiative, seek to understand how current skills and the social and material context resist and support change. Direct resources to developing skills, addressing the material environment and adjusting collective ideas to facilitate change in doings. Analysing and working on tensions and resistance can provide valuable information for policy and product development which is not solely limited to application characteristics and design.
4. When designing a data-based application and related initiatives, specify the mechanism planned to support rearrangement of the targeted doings in everyday life. Importantly, think beyond providing information and advice. Focus on how you can support people in real life to rearrange everyday doings. In other words, attend to how the surrounding environment could better facilitate the change.
5. Intermediaries are key actors in integrating applications into their work in advancing environmental sustainability and education or modifying their products and services to attain environmental goals. Consider how to integrate data and applications as tools and guidance into key working processes and activities.
6. When planning the monitoring of the use and impact of data-based measures, include qualitative methods to observe the (non-)integration of applications to doings and seek to identify reasons (not) to act according to feedback and suggestions. Consider methods of data collection which can capture actual doings as intentions may not equal actions. Remain open to tension arising from everyday life circumstances and (conflicting) priorities in addition to the characteristics of the application and activities of the initiative.

As highlighted, many actors from private to public organisations have launched data-based applications and activities to inform people and steer consumption, and are likely continue to do so in the future. Here, I return to underlining the difference between steering consumers and consumption. To simplify, steering consumers focuses on informing and persuading consumers to make 'the better choice', whereas steering consumption maps the elements of the unsustainable practice and seeks ways to rearrange them more beneficially. I argue that public policymaking, in particular, has a

responsibility to tackle the challenges of changing collective doings and steering the elements that support and facilitate them.

5.3 FUTURE RESEARCH DIRECTIONS

More research is needed on the potential role of consumption-based data in all categories of sustainable consumption policy instruments, not only informational instruments. Moreover, the materiality of consumption, such as its physical infrastructure, which affects prevalent practices and consumption, should be recognised and policies be designed to steer through material rearrangements.

As several previous studies have concluded, shifts in household consumption patterns and practices could deliver a major decrease in emissions with the already existing technologies, products and services. Furthermore, according to practice thinking, elements of more sustainable practices may exist, but they remain disconnected. Research focusing more closely on the role of data in steering everyday professional or personal practices should apply approaches that can capture the complexities of place-specific settings. Starting from the data perspective, identifying the uses of data and applications to enhance connections between sustainable building blocks of the everyday is required.

Quantitative data is important in order to direct attention to major sources of emissions and verify whether changes in consumption are realised in large populations. At the same time, I argue that the use of qualitative approaches to map processes of (non-)change of consumption from a systemic perspective is required to further understanding of the dynamics of change and the roles of steering measures. The tensions and frictions in real life seem to play an important role in how the data and applications are integrated into steering doings.

Hence, I also call for research approaches with the sensitivity to recognise issues that should be tackled with other steering measures and policies than the data-based applications studied in this dissertation. Further understanding is needed on how consumption-based data can support setting targets, drafting road-maps and making decisions on climate and other environmental actions in municipalities and cities, for instance. In this context, many decisions with long-term impacts should be made to shape the everyday environments and, thus, consumption patterns.

To summarise, strengthening the understanding of the role and use of consumption-based data in policy, in processes setting the scene for consumption and in guiding the doings of people in their everyday lives is called for. The role of data-based policy mixes and measures requires rethinking, especially in regard to how and for what purposes applications could be useful in addition to improving the applications as stand-alone tools.

5.4 CLOSING REMARKS

Lastly, I return to my motivation for writing this dissertation. I was puzzled about the role, challenges and potential of carbon footprint calculators and similar applications in steering household consumption from the environmental perspective. This study has unpacked the complexity of some of the challenges facing applications in contributing to shifting towards smaller carbon footprints. I think the findings are timely given there is an urgent need to identify and implement measures to mitigate climate change and other environmental challenges.

I was writing the summary part of this dissertation when the Covid-19 pandemic struck in 2020. The times illustrated how stringent measures can be introduced quickly, as governments enforced strict restrictions to slow down the spread of the disease. Restrictions led to change in a wide range of everyday practices, including ways of working, education, shopping, travelling and communication, as people adapted as best they could in all areas of life. It is beyond the scope of this thesis to discuss the pandemic in more detail; however, I find that the exceptional times showed that combinations of stringent regulations and less formal steering measures to change what people do can be implemented quickly when reliance on information-based voluntary measures is not seen to be powerful enough.

In terms of using data to steer doings and consumption for environmental sustainability purposes, I argue that understanding the role of information and data-based applications in the context of the complexities of everyday life is of growing importance. At the time of writing this thesis I saw many novel initiatives experimenting with means to combine GHG emission data with purchase and consumption data, and to communicate it to people. Integrating databases and many other improvements into emission estimation methodologies is an essential step forward but unlikely to solve frictions in changing doings that arise from the surrounding society. My sincere hope is that this dissertation provides some insights and inspirations for future research on the topic.

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